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Habitat selection and use by bighorn sheep (Ovis canadensis) on a northwestern Montana winter range

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HABITAT SELECTION AND USE BY BIGHORN SHEEP (*Ovis canadensis*) ON A NORTHWESTERN MONTANA WINTER RANGE

By

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Winter habitat selection and use by bighorn sheep were investigated near Thompson Falls in northwestern Montana. Between 1 January and 30 March 1976, 197 observations of groups of wintering bighorns provided data on group size, herd sex and age characteristics, movements, home range, and habitat selection. Mean group size was 5.6. Lamb:ewe and yearling:ewe ratios were 92:100 and 42:100, respectively. Minimum winter home ranges averaged 320 acres (130 ha) for adult females and 271 acres (110 ha) for adult males. Wintering bighorn sheep selected against elevations above 4,800 feet (1,463 m), drainage bottoms, upper slopes, areas with a slope steepness of 10-35 percent, east and southeast aspects, areas greater than 0.2 miles (322 m) from steep terrain, closed forests, and the *Pseudotsuga menziesii*/*Physocarpus malvaceus* habitat type. Preferences were shown for cliffs, areas with a slope steepness greater than 80 percent, areas within 0.2 miles (322 m) of steep terrain, shrubland-grasslands and open forests, and the rockland-scree habitat type category. Adult ram groups were observed at significantly higher elevations than ewe-juvenile or young ram groups. Wintering bighorn sheep apparently sought out warmer elevations of the mountains. Mean group size was lowest during periods of decreasing barometric pressure. Percentages of grasses and sedges, browse, and forbs in fecal material were 38, 51, and 11, respectively. Forage utilization was greater above 3,800 feet (1,158 m) elevation than below. There was general agreement on the relative use of habitats by bighorn as estimated by fecal group counts and direct observations of wintering animals. Perpetuation of shrubland-grassland and open forest cover types on the winter range as well as a long-term monitoring program involving the systematic collection of data on herd sex and age characteristics, lungworm loads, and forage utilization levels were recommended.

ERRATA SHEET for M.S. Thesis by Mark Tilton-- Habitat selection and use by bighorn sheep on a northwestern Montana winter range

Tables 9,10,11,12,13,14,15

The columns under the heading "Confidence interval on proportion of group observations (90% family confidence coefficient)" should be in the form: $.159 \leq Po \leq .263$ (example from table 9 page 61)

The last line on these tables should be: "Pa < confidence interval on Po = Preference; Pa > confidence interval on Po = Avoidance; Pa within confidence interval on Po = None." This line should be added to the bottom of Table 10.

Table 16 page 75

First column	should be
2800 feet	≤ 2800 feet
4800 feet	> 4800 feet
.1 miles	≤ .1 miles
.41 miles	≥ .40 miles
80 percent	> 80 percent

Table 9 page 61

First column	should be
2800	≤ 2800
4810	≥ 4810

Table 11 page 65

First column	
80	should be > 80

Table 13 page 69

First column	should be
.41	≥ .41
(.66 km)	(≥ .66 km)

Figure 17 page 77

Temperature (°C) should be Average daily temperature (°C). The title of the graph should be: " Fig. 17. Average daily barometric pressures (top) and average daily temperatures at two elevations (bottom) during the study period."

Literature cited page 120

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39(2):387-401.

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CHAPTER I

INTRODUCTION

The history of the bighorn sheep population near Thompson Falls in northwestern Montana parallels that of many other bighorn sheep concentrations in the western United States. Fur trappers described sheep as numerous in the area in the 1830's and 1840's (Cox 1831, Ferris 1873). Shortly after the turn of the century, these sheep were greatly reduced in numbers and their distribution drastically restricted. Couey (1950) reported that the Thompson Falls population was restricted to a small portion of their former range and estimated the population at 25 sheep in the early 1940's. The decline apparently led to the complete extinction of the local herd, as no bighorn sheep were sighted in the area after 1948 (Brown 1974). Buechner (1960) reported a similar trend in the 15 western states historically inhabitated by bighorn sheep. He found that they occupied approximately 10 percent of their former range and their numbers were reduced substantially to a 1960 estimate of less than 20,000. Bighorn sheep were exterminated in four of the 15 states.

In 1959, two transplants of bighorn sheep, totaling 13 ewes and six rams, were made into the Thompson Falls area. A study of the distribution and population characteristics of the resulting herd was carried out in 1973 and 1974 by Brown (1974). He reported that the herd had expanded its range to include 140 square miles (363 sq. km) of mountainous terrain and numbered approximately 240 individuals.

Brown's (1974) investigation identified two herd segments within the population, with interchange apparently restricted to rams. Relatively high body weights, rapid horn growth, early physical maturity, high productivity, and low lungworm levels indicated a healthy population. Brown's pilot study to assess the current status of mountain sheep in the Thompson Falls area resulted in a recommendation for "a follow-up to determine the carrying capacity for ungulates, as reflected by range conditions." Brown postulated that a future population crash was probable due to a rapidly expanding population in a region where severe winters occur sporadically. He proposed a preventive management program consisting of an expanded hunter harvest and/or removal of animals for transplanting stock on a sustained basis to stabilize the population. The present study of winter habitat relations was designed to provide information on the critical management question of carrying capacity.

Many other investigators have recognized the importance of winter habitat characteristics in the ecology of Rocky Mountain bighorn sheep (Honess and Frost 1942, Smith 1954, Buechner 1960, Oldemeyer 1966, and Rutherford 1972a). Smith (1954) stated "Just as winter and early spring is the critical period in the life of the bighorn, so is the abundance and condition of available winter range a determining factor in his survival." In his classic monograph on bighorn sheep, Buechner (1960) stated that the poor conditions of winter ranges in Wyoming and Montana were the principal limitations to population sizes. He recommended intensive research on crucial winter ranges as essential to bighorn sheep conservation efforts. Oldemeyer (1966) stated that further research into bighorn sheep winter ecology was needed. While it should not be assumed "a priori" that winter range conditions are the limiting factor for a particular bighorn sheep population, investigations on this potentially critical seasonal range should probably be given priority unless local conditions suggest possible limitations on other seasonal ranges.

Recent studies have yielded some information on habitat use by wintering bighorn sheep. Oldemeyer (1966) reported small patches of conifers and deep ravines were often utilized as shelter with the onset of falling snow and wind. He found that wintering bighorns preferred south, southwest, and west facing slopes on steep, rocky terrain or ridge tops. Geist (1971), in discussing the behavior of mountain sheep on winter ranges, stated "they appear to prefer the warmest elevations of the mountains, keeping in the warm air above the thermocline." Geist reported observing bighorn sheep avoiding deep snow except when the crust supported their weight. Shannon et al. (1975) related seasonal distribution of ewe-juvenile groups of bighorn sheep to 11 environmental variables. Stelfox (1975) reported a highly significant positive correlation between barometric pressure and numbers of sheep on exposed grasslands during winter. He also found a significant negative correlation between snow depth and numbers of sheep on those ranges. Geist (1971) stated that as a general adaptation to winter "mountain sheep typically reduce waste of energy by avoiding excessive heat loss and excessive energy expenditures in foraging and social life, while maximizing energy gain and retention for the lowest possible expenditure."

Energy relationships between an animal and its environment have recently received increased attention. Variations in habitat structure and ambient meteorological conditions that influence energy expenditure have been reported to influence winter range distribution of several ungulate species in addition to bighorn sheep. Snow depth and forest canopy characteristics were reported to be correlated with moose (Alces alces) and white-tailed deer (Odocoileus virginianus) distribution by Telfer (1970). Kelsall and Prescott (1971) reported snow depths were important in determining moose and white-tailed deer distribution. Gilbert et al. (1970) found snow depths in excess of 18 inches (46 cm) essentially precluded range use by mule deer (O. hemionus). Interactions of snow depth and crust hardness were an important parameter in moose-wolf (Canis lupus) relationships (Peterson and Allen 1974). Loveless (1967) observed responses of wintering mule deer to variations in solar radiation, air temperature, atmospheric moisture, snow conditions, browse availability, and interspersion of food and cover.

The planning stages of the present study were strongly influenced by the results of a study by Beall (1974) of elk (Cervus elaphus) winter habitat selection and use. He reported that feeding site habitat selection by elk was affected by snow depth, ambient temperature, radiation, wind velocity, slope position, and timber stand density. He also found that elk bedding site distribution correlated with slope, aspect, slope position, and stand density. Different habitats were selected under varying meteorological conditions. In addition, elk had a tendency to bed near the largest tree available in the immediate vicinity of the bedding site. Potential relationships between characteristics of coniferous tree cover and bighorn sheep bedding sites have not been adequately investigated. Such information would be useful in evaluating the impact of logging activities and prescribed burning programs on bighorn sheep winter ranges.

Quantitative information on ungulate distribution in relation to ambient meteorological conditions and biotic and abiotic environmental variables is necessary if the portions of winter range that may be critical to the survival of animal populations are to be identified. A better understanding of winter habitat selection would allow concentration of range management efforts on key areas. At the present time, information concerning the distribution of bighorn sheep on their winter ranges in relation to potentially important environmental variables is lacking. Winter habitat selection by many different populations of bighorn sheep must be investigated in depth if the survival strategies and capabilities of the species are to be fully understood. Results from the present study should contribute information toward this objective.

Information on the use of winter habitat has important management implications since the transplanting of bighorn sheep into formerly occupied areas has become a widely used game management technique for increasing distribution and abundance (Yoakum 1963). Rutherford (1972a) pointed out that evaluation of potential transplant sites was complicated by the facts that bighorn sheep were very selective and their habitat requirements were not well understood. This lack of knowledge is apparent when the success rate of transplanting operations is examined. Although all of the transplant sites in Colorado were judged to offer excellent opportunities at the time the releases were made, only eight of 14 transplant sites were occupied in 1972 by successful populations (Rutherford 1972b). In Montana, Couey and Schallenberger (1971) reported that seven transplant sites contained surviving or huntable populations, five were failures, and the status of seven other transplants had not been determined. The Thompson Falls population, the result of a transplanting operation, is a particularly relevant population for study. Information gained in the present study may be useful in evaluating potential winter ranges on proposed bighorn sheep transplant sites.

The present study, designed to investigate winter habitat selection and use by mountain sheep in the Thompson Falls area, was conducted from June 1975 through July 1976. Specific objectives were to:

1) quantitatively describe the habitat available to wintering bighorn sheep;

2) determine winter habitat use by bighorn sheep and other wild ungulates;

3) evaluate winter habitat preferences of bighorn sheep in relation to biotic and abiotic environmental variables;

4) characterize bighorn sheep winter bedding site habitat; and

5) quantify forage utilization on key-use areas within the winter range.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

Selection

The Thompson Falls bighorn sheep population was well suited for the present intensive winter study. Brown's (1974) pilot study defined basic seasonal distribution patterns and population characteristics of the herd. A number of bighorn sheep, individually marked by Brown, remained in the population and could provide information on individual movements and use patterns. The portion of the winter range selected for the present study offered a wide variety of elevational, topographical, and vegetational habitat choices to wintering ungulates. This diversity within the study area was considered important for evaluating possible habitat selection by bighorn sheep.

Location and Ownership

The Thompson Falls bighorn sheep range is situated in the southeast end of the Cabinet Range along the north side of the Clark Fork River midway between Plains and Thompson Falls, Montana (Fig. 1.). Map coordinates are 115° 00' - 115° 15' W. longitude and 47° 30' - 47° 45' N. latitude. For a detailed description of this area see Brown (1974).

The present study was conducted on a 4,102 acre (1,660 ha) portion of this bighorn sheep range adjacent to State Highway 200 (Fig. 2.).

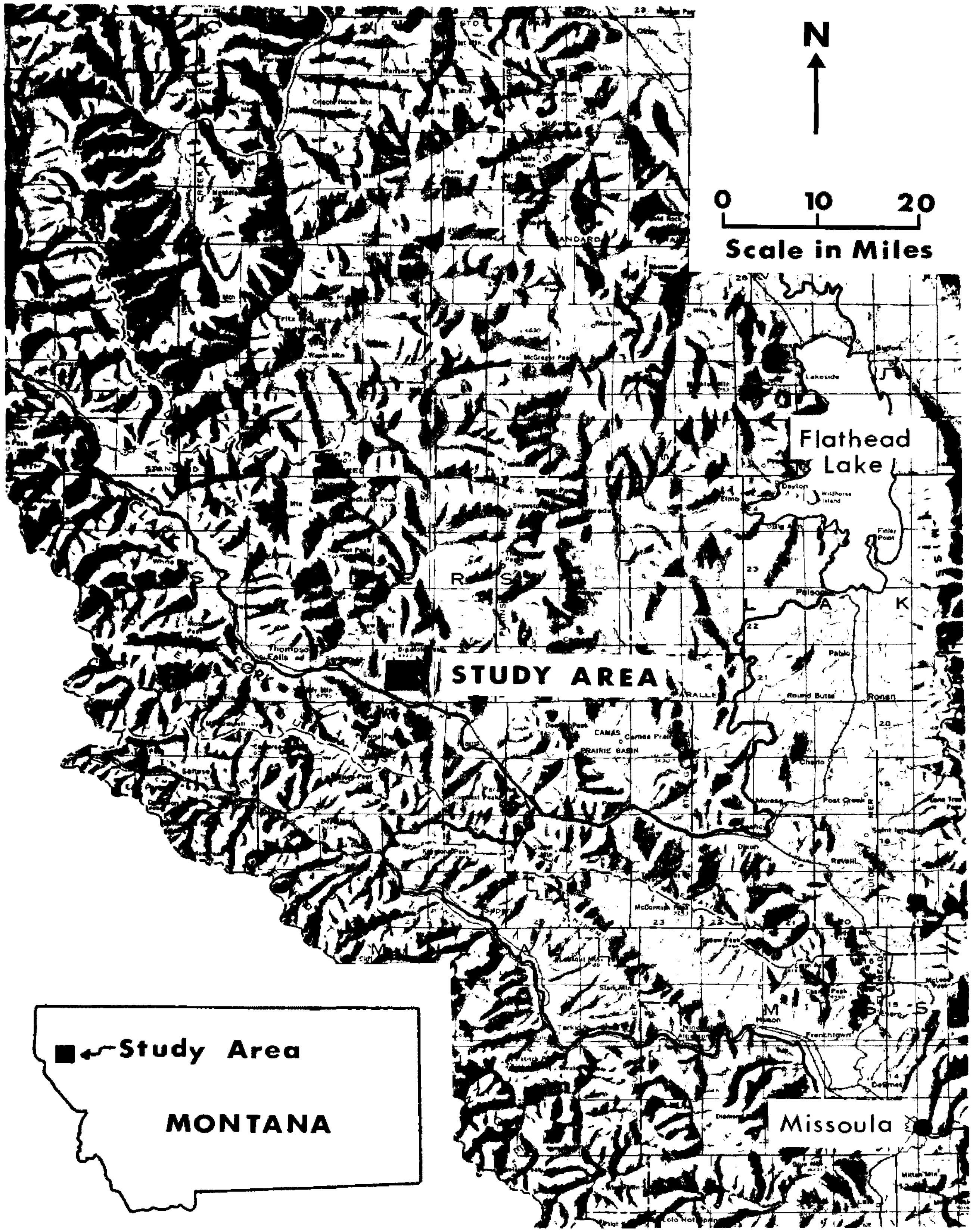

Fig. 1. Location of study area.

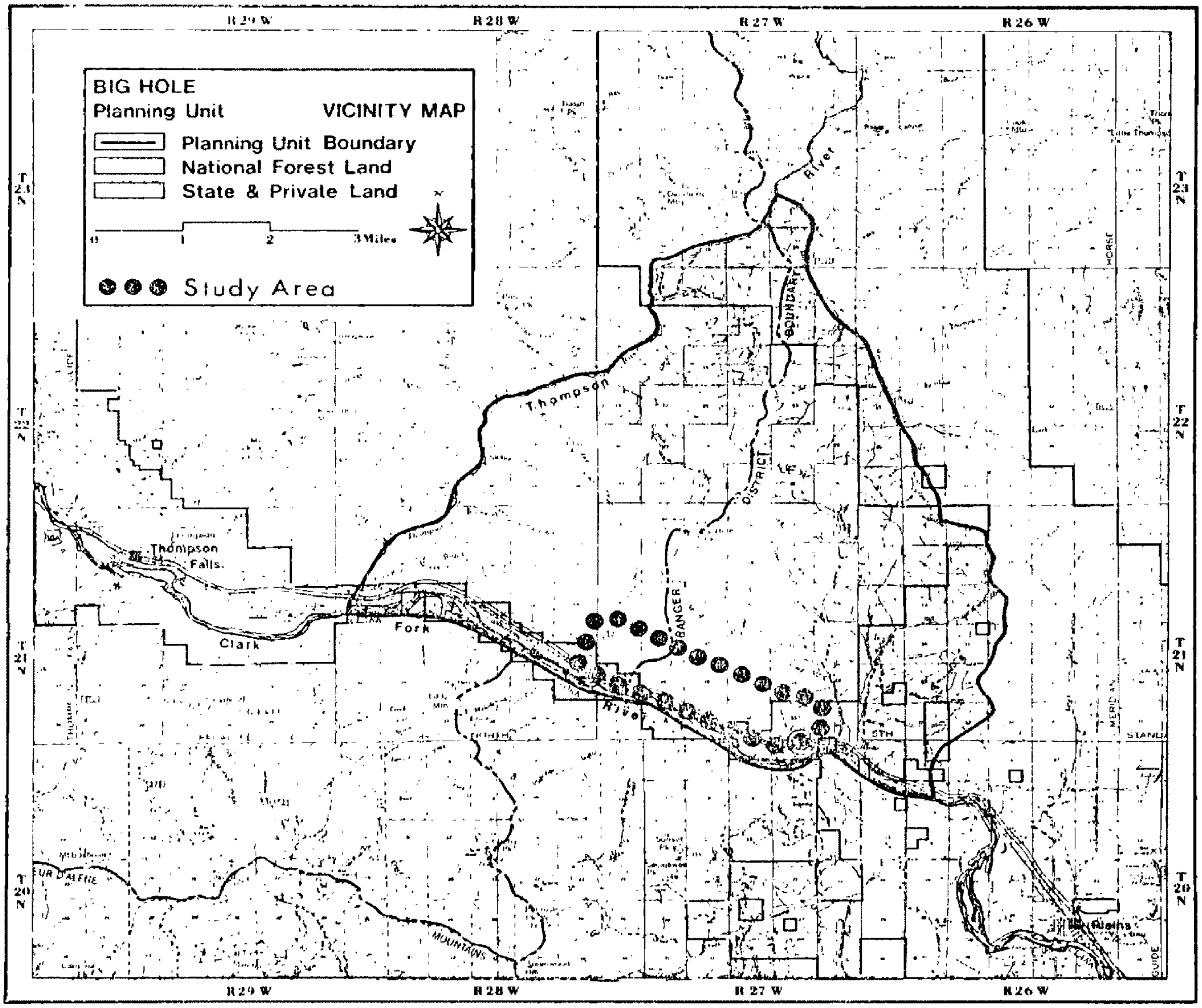

Fig. 2. Location of Big Hole Planning Unit, Lolo National Forest (adapted from Anonymous 1976).

The study area is bordered roughly by Weeksville Creek on the east, Munson Creek on the west, Highway 200 on the south, and on the north, by the north slope-south slope divide overlooking the Clark Fork River Valley. The entire study area is within the region bounded by map coordinates 115° 00'00" - 115° 07'30" W. longitude and 47° 31'25" - 47° 34'36" N. latitude.

The study area is in the Big Hole Planning Unit (BHPU) on the Lolo National Forest (Fig. 2.). Section 35 and portions of section 36, T21N, R27W comprise most of the private land. In 1976, the U.S. Forest Service issued a Draft Environmental Statement concerning the proposed Multiple Use Plan for the BHPU. That document was a primary source for information contained in this chapter.

Topography and Geology

Brown (1974) described geologic structure and geomorphic features for the entire sheep range. The portion of his description relevant to my study area reveals that local topography was greatly influenced by massive Glacial Lake Missoula. With the rupture of the glacial ice dam near Sandpoint, Idaho, the Lake's waters were rapidly discharged at an estimated rate of 8 to 10 cubic miles (33 - 42 cu. km) per hour (Alt and Hyndman 1972). Lake sediments and residual soils were washed from the walls of the narrow Clark Fork Valley between Plains and Thompson Falls resulting in exposure of parent material. This section of the Valley is characterized by poorly developed soils and numerous talus cones emanating from rugged crags of exposed bedrock. From the Valley floor at approximately 2,400 feet (732 meters), the mountains rise to over 5,900 feet (1,798 meters) in less than 1.5 miles (2.4 km). Alden (1953) reported that the gorge transected an anticline composed mostly of Precambrian quartizite.

The general orientation of the Clark Fork Valley within the study area is northwest to southeast. As a result, south to southwest exposures predominate. West and east exposures occur within five secondary drainages oriented in a north-south direction. Among these secondary drainages, only Munson Creek and Weeksville Creek have cut down to the Clark Fork Valley floor. The other three drainages are hanging valleys whose mouths terminate above 3,400 feet (1,036 meters).

Climate

Climatic characteristics pertinent to the study area have been described by Brown (1974) and the U.S. Forest Service (Anonymous 1976). Brown (1974) stated:

> "The Clark's Fork River Valley between Plains and Thompson Falls reputedly has the mildest weather conditions in northwestern Montana. This is due mainly to the northwest-southeast alignment of mountain ranges. The Coeur d'Alene Range to the southwest blocks out much of the moisture-laden air moving inland from the Pacific Coast, while the Cabinet Range to the northwest shelters the area from cold air masses moving south from Canada."

The prevailing flow of air aloft is from the west and southwest during spring and summer, shifting to more northerly directions during fall and winter. The study area is therefore dominated by a Pacific maritime climate characterized by a warm, moist spring and a fairly long, dry, and hot summer followed by wet, cool fall and winter seasons (Anonymous 1976). Precipitation and temperature often vary greatly within the study area due to marked elevational differences.

Abrupt seasonal and daily changes of weather are common. This is especially true when continental air masses occasionally overtop the sheltering Rocky Mountains (Anonymous 1976). This reversal of normal circulation often results in extremes of temperature and/or precipitation.

Climatological data for the U.S. Weather Bureau were collected by the Montana Power Company at their hydroelectric plant in Thompson Falls, approximately 12 miles (19.3 km) from the study area. During the 30 year period ending in 1970, the average annual temperature was 47.5° F (8.6° C). January was the coldest month averaging 26.5° F (-3.1° C) with a range from -36° F (-37.8° C) to 56° F (13.3° C). July and August were the warmest months with monthly means of 68.5° F (20.3° C) and 67.2° F (19.6° C), respectively. The range of recorded temperatures in July was 35° F (1.7° C) to 109° F (42.8° C) in the 30 year recording period.

Mean annual precipitation was 22.5 inches (57.2 cm). November, December, and January had the most precipitation, with a secondary peak in June. Snow and ice pellet precipitation records indicated the highest average amounts in December, January, February, and March.

The average annual precipitation within the study area, as estimated by the U.S. Forest Service, varies from approximately 19 inches (48.3 cm) to over 50 inches (127 cm). The precipitation pattern for the entire BHPU is described in the Draft Environmental Statement Multiple Use Plan (Anonymous 1976) as follows:

> "Total annual precipitation ranges from 19 inches along the Clark Fork River Valley to about 75 inches at the summit of Big Hole Peak . . . This unit is on the edge of a rain shadow area produced by the higher elevation Bitterroot Mountains to the west. Rain and snow amounts at any given elevation in this planning unit are less than comparable sites to the west, but greater than lands immediately east of the planning unit . . .
>
> Distribution of total precipitation between snow and rain is conditioned by season and elevation. Snow accounts for about 25 percent of low elevation precipitation and increases to 70 percent or more along the high ridges and peak areas . . .
>
> As elevation increases within the unit it can be assumed that precipitation will increase in amount, intensity and seasonal variance, but the general pattern established at Thompson Falls will likely persist over the entire planning unit."

In order to evaluate the data from the present winter study, comparison was made of weather conditions during the study period and those of previous winters. Listed in Table 1 are several temperature and precipitation parameters recorded at the Thompson Falls weather station during the 1975-1976 winter, the severe winter of 1968-1969, and corresponding mean and extreme values for the 30 year period ending in 1970. The 1975-1976 winter was average to mild. Total winter precipitation was somewhat higher than average, due mainly to heavy rainfall in December. Temperatures were near normal for December and February, January was warmer than the 30-year average and March was cooler. Simultaneous high precipitation and low temperatures, characteristic of a severe winter for this weather recording station, did not occur in any month.

An index of winter severity was calculated for the 1975-1976 winter, the 1968-1969 winter, and the 30-year average using the method described by Peek et al. (1976). The index was derived by subtracting the mean monthly temperature from 32° F (0° C), multiplying the remainder by the corresponding monthly precipitation, and adding the monthly (December through March) products. This method rated the 1975-1976 winter as slightly less severe (1.36) than the 30-year average (7.94). The 1968-1969 winter had a severity index of 100.5 at the Thompson Falls weather station. Peek et al. (1976) reported a 12-year average in northeastern Minnesota of 89.15. A winter that rated 76.93 during that study was considered about normal. Severity indexes of 182.15 and 45.76 were judged more severe and much less severe, respectively, than the 12-year average.

Vegetation

The floristic composition in the Thompson Falls region reflects the Pacific Coast climatic influence (Brown 1974). Species common to the west coast such as western red cedar (*Thuja plicata*), grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), mountain hemlock (*Tsuga mertensiana*), and western yew (*Taxus brevifolia*) occur in the vicinity of Thompson Falls. Brown reported a species list for his study area.

The present study area was included in a vegetation description of the BHPU based on habitat type inventories (Anonymous 1976). The

Table 1. Winter weather data recorded at Thompson Falls, Montana during the study period (1975-1976), a severe winter (1968-1969), and the 30-year period of 1941-1970.

Period	Mean Monthly Temperature (^{o}F)	Temperature Extremes		Total Precipitation (inches)
		Maximum	Minimum	
1975-1976				
December	30.4	49	6	4.00
January	30.3	48	4	2.54
February	33.1	55	3	2.54
March	35.8	68	5	1.73
1968-1969				
December	25.2	43	-25	3.58
January	19.4	40	-6	6.14
February	29.0	46	9	1.04
March	36.6	67	7	1.07
1941-1970				
December	30.1	68	-25	2.50
January	26.5	56	-36	2.61
February	33.0	64	-30	1.85
March	38.0	78	-10	1.72

classification of habitat types on the basis of potential climax tree species and characteristic understory plants was according to Preliminary Forest Habitat Types of Western Montana (Pfister et al. 1972). The habitat types were then grouped according to Habitat Type Inventory Standards and Procedures for Multiple Use Planning (Anonymous 1973). The study area was classified primarily as rockland and scree by this broad habitat group system. Small areas of the Douglas-fir (*Pseudotsuga menziesii*)/shrub group were identified at middle to high elevations. The queencup beadlilly (*Clintonia uniflora*) group, containing grand fir and western red cedar, was restricted to stream bottoms. The ponderosa pine (*Pinus ponderosa*) and dry beargrass (*Xerophyllym tenax*) groups were reported on the periphery of the study area at low and high elevations, respectively. Detailed descriptions of each habitat group may be found in Brown (1974) and Anonymous (1976).

Fire History

An analysis of the BHPU (Anonymous 1976) by the U.S. Forest Service stated: "Fire has greatly influenced life forms in the planning unit. Almost all the present plant and animal species in the natural ecosystem are dependent on fire for their perpetuation. Some plant species require fire's heat to open seeds or provide openings for regeneration and growth."

Evidence of past fires are found throughout the study area (Fig. 3). Much of the Munson Creek Drainage burned in 1889. In 1945,

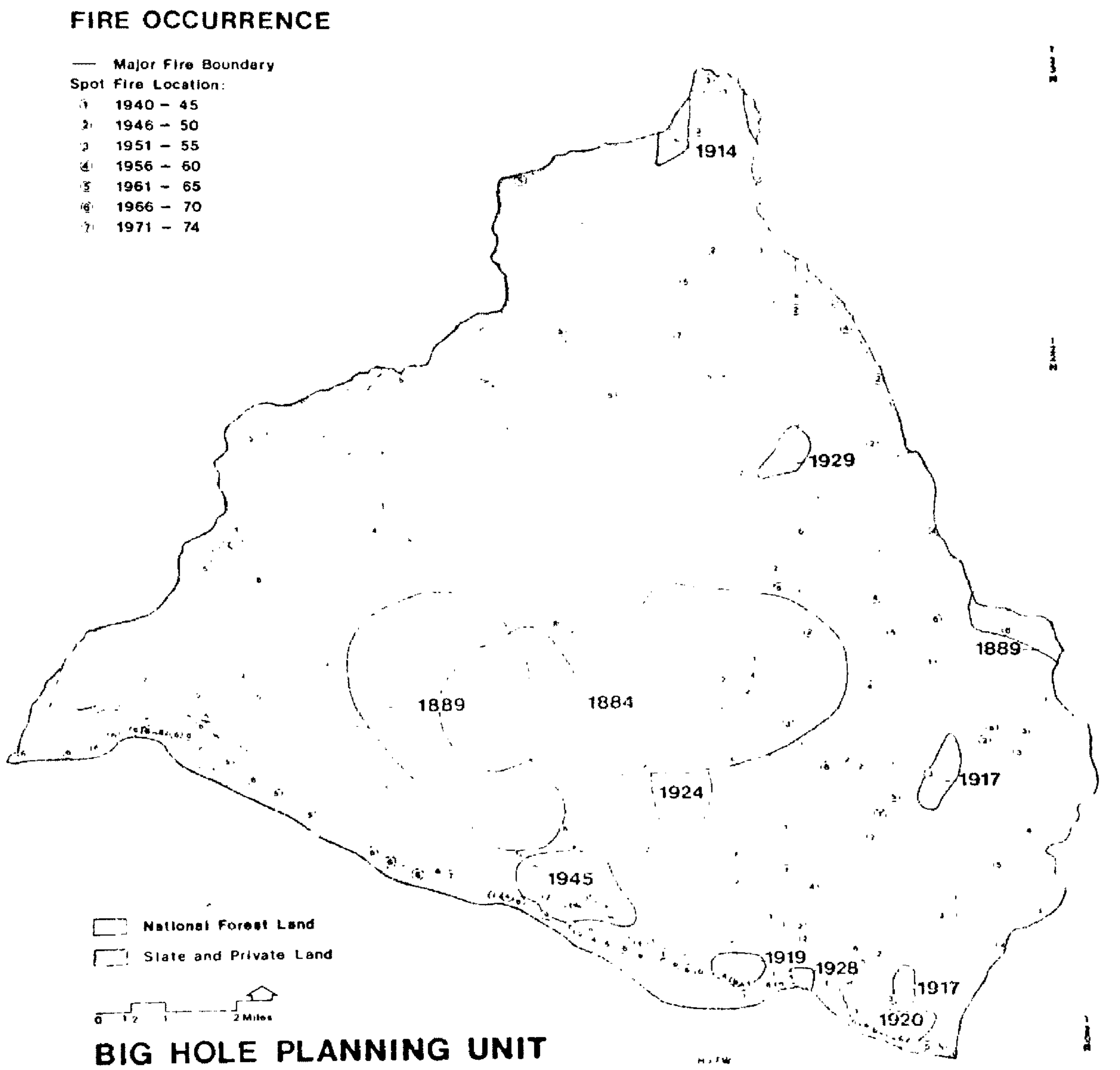

Fig. 3. Fire history of the Big Hole Planning Unit, Lolo National Forest (adapted from Anonymous 1976).

over 600 acres (242.8 ha) burned along the Clark Fork Face, including nearly all of one upper elevational valley. Numerous spot fires occurred throughout the study area.

Land Use

Timber resources on the federally owned land within the BHPU were inventoried by the U.S. Forest Service (Anonymous 1976). The steep, rocky face along the Clark Fork River Valley, which comprised the major part of the study area, was classified non-forest and non-commercial forest. Potential timber producing areas of seedlings, poles, and sawlogs, primarily at higher elevations, were identified. Section 35 and the portion of Section 36, T21N, R27W, within the study area contain both sawlog and non-commerical forest land. This privately owned land is the only part of the study area that has been logged.

Currently one National Forest grazing allotment is issued in the Munson Creek area. Section 35 and a portion of Section 36 T21N, R27W have been grazed by cattle for several years.

The BHPU is not considered a significant area for recreation in the Lolo National Forest (Anonymous 1976). The pressure on the study area for day hiking and overnight camping is limited because of steep topography, limited trail and road development, and scarcity of water. The hunting of bighorn sheep, mule deer, white-tailed deer, and black bear (*Ursus americanus*) results in light recreational use. Viewing of bighorn sheep along Montana Highway 200, particularly in the spring and early summer, is the major recreational use of the study area.

CHAPTER III

MATERIALS AND METHODS

Capture and Marking Techniques

Brown (1974) reported 19 bighorn sheep marked with rope-flagging collars in the Thompson Falls population as of April 1974. I trapped during the summer of 1975 in an attempt to complete marked cohorts for all sex and age classes. A portable corral type trap (Bodie and Hickey 1976), provided by the Idaho Department of Fish and Game, was installed at a heavily used lick site previously located by Brown (1974). A clover trap provided by the Montana Fish and Game Department was installed in close proximity to the corral trap for use as a holding pen for lambs. The corral trap was baited with two 50 pound (22.7 kg) blocks of salt (NaCl 99 percent, inert matter 1 percent). A manually operated triggering device allowed selectivity in number and age-sex composition of animals captured.

Trapped animals were manhandled and their legs secured in a fashion similar to that of tying up a calf. Tranquilizing drugs were not used. Each animal was marked with a color-coded rope-flagging collar (Craighead et al. 1969). Each collar consisted of four flags in combination with white rope for males and yellow rope for females. Each collar included either a reddish brown or black numbered pendant, which facilitated individual identification at close range. The four color-coded flags identified animals at longer distances. Inside circumferences of collars were 24 inches (61 cm) for ewes and 28 inches (71 cm) for rams, as recommended by Brown (1974).

Live weights were obtained, when possible, with a Chatillion type-160 spring scale. Observations of marked sheep provided data on home ranges, daily movements, and habitat use.

Temperature and Snow Measurements

Four recording thermographs provided continuous temperature records at 2,700; 3,500; 4,300; and 5,100 feet (823; 1,067; 1,311, and 1,555 m) elevations on open south to southwest slopes. The thermograph data provided an accurate means of determining temperature at times of sheep observations. The thermographic records were also useful for identification of inversion conditions characterized by warming temperatures with increasing elevation.

Snow measurement stakes were erected to sample snow depths at approximately 400 feet (122 m) elevational intervals on south to southwest aspects of the study area. Snow stakes were placed in both open forest and closed forest plant cover types at each elevation. Similar stations were placed at 3,100; 4,300; and 5,100 feet (945; 1,311; and 1,555 m) elevations on east and west aspects.

Observations of Ungulate Distribution

From 1 January to 30 March 1976, animal use was assessed by direct ground observations of ungulates and ungulate signs (tracks, beds, and fecal groups) from five predetermined routes. Four routes, selected to collectively sample the entire study area, were covered on foot. One vehicular route consisted of nine predetermined observational points adjacent to Highway 200.

The routes were traveled at intervals of approximately 1 week. Each route traveled on foot took an entire day to complete. The vehicular route was traveled in the afternoon as this was the time of greatest sheep activity (Brown 1974). Fifteen to 30 minutes were spent at each highway observational point. The vehicular route was traversed in opposite directions during alternate counts.

The open nature of the Clark's Fork face facilitated direct ground observations. However, bighorn use of dense timber stands was potentially underestimated by this method. Fortunately, the majority of closed forest stands on the study area occurred at higher elevations where snow conditions usually permitted the collection of track data in addition to direct observational data.

Direct observations were aided by the use of 7 x 26 mm binoculars and a 15-60x variable spotting scope. Upon initial observation, the time of day, location, type of activity, abiotic and biotic habitat characteristics, meteorological conditions, age and sex composition, and number of marked animals were recorded numerically for each group. Identity of marked animals, notes on behavior, and reobservations were entered on the back of 3 x 5 inch (7.6 x 12.7 cm) datum cards. Only one record per day was made for each group.

No attempt was made to distinguish between male and female lambs or yearling and adult females. Males 18 months and older were divided into horn length classes (Geist 1971). These males were recorded as yearlings ($<$ 1/2 curl), young rams ($\geq$ 1/2 $<$ 3/4 curl), or adult rams ($\geq$ 3/4 curl).

The activity of the group when first spotted was categorized as bedding, feeding, bedding and feeding, standing alert, traveling, or fleeing. Traveling was defined as animals actively engaged in moving from one location to another at a walking pace. Fleeing consisted of animals running from one location to another.

Each group sighting was located on a USGS 7.5 minute topographic map overlaid with a 0.1 mile (0.16 km) grid. A four digit numerical coding scheme with the first two digits identifying individual square mile portions of the study area and the last two digits identifying 0.1 mile (0.16 km) east-west and north-south coordinates within each square mile was employed to record each location. The location was recorded numerically as the nearest grid intersection point.

Movements and Home Range

Movements, winter centers of activity, and minimum home range sizes for marked sheep were determined from ground observational data. The centers of activity for individually tagged animals were defined on topographic maps using a grid overlay system as explained by Hayne (1949). The centers of activity were used with Harrison's (1958) formula ($SD = \sqrt{\Sigma D^2/N}$) to calculate the standard diameter (SD) for each marked animal. D is twice the distance from the center of activity to each relocation, and N is the total number of relocations.

The standard diameter represents the diameter of a circle with the center of activity as its center, and which contains 68.26 percent of all relocations of an animal during the period considered. Relocations plotted on gridded topographic maps were connected to delineate individual minimum winter ranges. Areas of resulting polygons were measured with a polar planimeter (Craighead et al. 1973) to determine minimum winter home range sizes.

Vegetation Analysis

Existing vegetation description. A plant cover type classification scheme based on physiognomy and vegetational characteristics of potential importance to wintering bighorn sheep was developed for the study area. A minimum of 25 percent coniferous canopy cover was considered necessary for a community to be classified forest (Penfound 1967). Any land on which shrubs dominated the vegetation was considered shrubland. Lands dominated by grasses or grass-like plants were classified as grasslands. Canopy cover was the sole measure of dominance used to distinguish between cover types. The five plant cover types recognized within the study area are described below.

1) Rockland is characterized by a non-bryoid canopy coverage total of less than 25 percent. This type is essentially identical to Penfound's (1967) bryoland. The vegetative canopy cover is dominated by lichens growing on relatively stable talus slopes or rock outcrops.

2) Shrubland-Grassland Complex is characterized by canopy coverages of 0-24 percent for conifers, 25-100 percent for shrubs, and

1-75 percent for perennial bunch-habit graminoids. There are no large expanses of grassland on the study area. Graminoid cover varies dramatically with soil conditions and bluebunch wheatgrass (Agropyron spicatum), rough fescue (Festuca scabrella), and elk sedge (Carex geyeri) are locally abundant in this cover type. The Shrubland-Grassland Complex plant cover type is found at all elevations and on all aspects of the study area.

3) Open Forest is characterized by canopy coverages of 25-75 percent for conifers, 5-75 percent for shrubs, and 5-75 percent for perennial bunch-habit graminoids. Open forest occurs at all elevations on south to west facing slopes.

4) Closed Forest is characterized by canopy coverages of 76-100 percent for conifers, 1-100 percent for shrubs, and 0-4 percent for bunch-habit graminoids. Closed forest communities occur as stringers and islands at low elevations. At elevations above 3,500 feet (1,067 m), this type is found in extensive communities on east, west, and north slopes.

5) Riparian communities are characterized by the presence of broadleaf tree species such as black cottonwood (Populus tricocarpa), alder (Alnus spp.), willow (Salix, spp.) and quaking aspen (Populus tremuloides). The largest riparian community (6 acres; 2.4 ha) occurs on a wide bench at 3,200 feet (975 m) elevation in the Weeksville Creek area. Small stands of quaking aspen, a minor type on the study area, occur sporadically at the base of talus slopes.

Conifer canopy cover, conifer stand structure characteristics, shrub cover, and graminoid cover were sampled systematically on a portion of the study area containing representative examples of the four important plant cover types. Since the entire study area was not randomly sampled, the data generated should be viewed as only a general description of each cover type.

Conifer stem density was measured by the point-centered quarter method (Cottam and Curtis 1956) with the distances measured by a rangefinder for distances less than 100 feet (30.5 m) and estimated to the nearest 25 feet (7.6 m) for distances greater than 100 feet (30.5 m). To provide estimates of basal area, the dBH class of each tree encountered in the density measurements was recorded as 0-5 inches (0-12.7 cm), 5-11 inches (12.7-27.9 cm), 11-21 inches (27.9-53.3 cm), or $>$ 21 inches ($>$53 cm). Crown canopy cover was measured with a Model C forest densiometer (Lemmon 1957).

Circular plots of 0.01 acres (0.004 ha) were used to provide canopy coverage class estimates for individual shrub species and the perennial bunch-habit graminoid group. The coverage classes in percent cover were Trace ($<$ 1%), 1-5, 5-25, 25-50, 50-75, 75-95, and 95-100.

Potential vegetation description. In recent years, land management agencies in the Northern Rocky Mountain region have used habitat type methods of land classification extensively for resource management purposes. Daubenmire and Daubenmire (1968) developed a habitat type classification system for forests of northern Idaho and eastern Washington. Pfister et al. (1974) developed a similar system for forested lands of Montana.

A habitat type is "the aggregation of units of land capable of producing similar plant communities at climax . . ." (Pfister et al. 1974). Each forest habitat type is designated by a two component label representing the dominant tree species and the dominant or characteristic undergrowth species in the climax community (i.e., Pseudotsuga menziesii/Physocarpus malvaceus habitat type). Daubenmire and Daubenmire (1968) explained the reasoning behind an overstory/ understory classification scheme as follows:

> "In the northern Rockies, forest overstory and undergrowth occupy the land independently . . . The composition of the tree stratum at climax is more closely relatable to macroclimate than to soil. The undergrowth unions are relatively more sensitive to soil and microclimate than are the trees."

The utility of habitat types in forest management is explained by Pfister et al. (1974) as follows:

> "They provide a permanent and ecologically-based system of land stratification. Each habitat type encompasses a certain amount of environmental variation but the variation within a particular habitat type should generally be less than between types. Plant succession can be predicted for each habitat type and a similar response to management treatments can be expected on units of land within the same type."

This predictability of plant succession and response to management by habitat type holds great promise of applicability to wildlife management. Information on seasonal animal distribution and use of plant cover types and habitat types is necessary for the evaluation of relationships between plant succession and animal species. When these relationships are understood, the habitat type classification system may prove a valuable tool for resource managers concerned with the long-term management of wildlife populations.

The study area was categorized according to the habitat type classifications of Pfister et al. (1974). A habitat type map was drafted interpretively utilizing ground truth data, aerial photos, and topographic maps. The maximum allowable inclusion of other types within a mapping unit was 20 percent.

Determination of Habitat Use

Fifteen abiotic and four biotic environmental variables were considered as potential determinants of bighorn sheep spatial distribution on the winter range. These variables were measured in conjunction with all group sightings.

The abiotic factors considered and the methods of measurement are described below.

1) Elevation was measured to the nearest 10 feet (3 m) with a Thommens pocket altimeter.

2) Slope steepness was estimated from topographic maps and recorded as percent slope classes of 0-10, 10-35, 35-60, 60-80, and >80.

3) Topographic position was characterized as drainage bottom, lower slope, middle slope, upper slope, ridge, or cliff.

4) Aspect was measured with a Silva compass and recorded as N, NE, E, SE, S, SW, W, or NW.

5) Distance to the nearest cliff was measured in feet with a rangefinder if less than 100 feet (30.5 m) and was estimated to the nearest 25 feet (7.6 m) if greater than 100 feet (30.5 m). A "cliff" was defined as a vertical drop of at least 15 feet (4.6 m).

6) Distance to steep terrain areas of more than 80 percent slope and larger than 4 acres (1.6 ha) was measured on topographic maps and recorded to the nearest 0.1 mile (0.16 km).

7) Temperature at the time of each group sighting was estimated from the recording thermograph data and recorded in ^{o}Kelvin (^{o}C + 273). For sightings at elevations bracketed by thermograph stations (2,700 to 5,100 feet, 823 to 1,554 m), temperature was estimated by linear interpolation. If an inversion existed between two stations, it was assumed to occur exactly at the elevational midpoint between them. For sightings below 2,700 feet and above 5,100 feet (823 to 1,554 m) elevations, temperature was estimated by linear extrapolation assuming a lapse rate of 2 degrees Centigrade per 1,000 feet (305 m) elevational change.

8) Snow character was classified as powder, bottom crust, top crust, or wet. Depth of sheep tracks were measured when possible to provide an indication of crust support characteristics.

9) Wind condition was recorded as calm, steady, or gusty.

10) Wind direction was estimated with a Silva compass and recorded as N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, or NNW.

11) Wind speed was measured with a Dwyer wind meter and maximum and minimum values in a 2 minute period recorded in miles per hour.

12) Cloud cover was estimated by percent coverage classes of 0-10, 11-50, 51-90, and 91-100.

13) Precipitation was recorded as none, rain, sleet, hail, or snow.

14) Barometric pressure was obtained from a barograph housed approximately 12 miles (19.3 km) from the study area.

15) Barometric pressure trend for the 4 hours preceding each sighting was recorded as the slope of the line on the barograph record for that time period. Increasing pressure was recorded as positive and decreasing pressure as negative.

The biotic environmental variables recorded in conjunction with group observations are described below.

1) Cover type in the vicinity of each group of animals was recorded as rockland, shrubland, shrubland-grassland complex, open forest, closed forest, or riparian.

2) Habitat type in the vicinity of each group sighting was determined through the use of cover type data and a habitat type map of the study area.

3) Distance to the nearest conifer was measured with a range-finder for distances less than 100 feet (30.5 m) and estimated within 25 feet (7.6 m) for greater distances.

4) Conifer canopy coverage class in the vicinity of each group was estimated and recorded in percent as 0-24, 25-75, or 76-100.

Bedding Site Habitat Analysis

Bedding sites were encountered in conjunction with ground censusing activities and during search periods devoted primarily to their location. Back-tracking of animals in fresh snow and direct observation of animals served to identify individual beds. Use of each bed was estimated as occurring in the previous 4, 24, or 48 hours, or classified as unknown. When possible, sites were also classified as day beds or night beds. Nine abiotic and seven biotic environmental variables were measured at each bedding site.

The abiotic environmental variables considered and the methods of measurement are described below.

1) Elevation, slope, topographic position, aspect, distance to the nearest cliff, and snow character were recorded in the same manner as for group observations.

2) Width of ledge or ridge was measured with a rangefinder in appropriate topographic positions.

3) Snow depth was measured in centimeters at five locations in the vicinity of the bed and the results averaged.

The biotic environmental variables considered and the methods of measurement are described below.

1) Cover type and habitat type were recorded in the same manner as for group observations.

2) Conifer stem density and basal area were determined by the point centered quarter method with the bed as the sample point; dBH classes utilized were identical to those used for stand structure measurements.

3) Conifer canopy cover was measured with a Model C forest densiometer (Lemmon 1957) while standing in the center of the bed.

4) Distance to the nearest conifer and dBH class of the nearest conifer were determined from the point-centered quarter data.

Pellet Group Distribution

Ungulate fecal groups on a representative portion of the study area were sampled with 20 foot (6.1 m) diameter circular plots. A restricted random design was used to locate six transects along slope contours between 2,650 and 5,150 feet (808-1,570 m) elevation. One transect was located along a north-south ridgetop and sampled from 2,700 to 5,150 feet (823-1,570 m) elevation. The position of the initial plot on the ridgetop transect was located randomly. All of the transects were located on predominately south to southwest aspects in areas where sheep use during the winter was expected.

Pellet group plot centers were located 100 feet (30.5 m) apart and were marked with metal stakes. Plots were cleared of all fecal groups in December and the numbers of fecal groups deposited during the winter were counted in the first week of April. An ungulate fecal group was considered to be five or more pellets of the same general size, shape, hardness, and color (Bowden et al. 1969). Groups occurring on the plot periphery were counted if one half or more of their total area fell within the plot.

At the time of the spring count, numerous site factors associated with each plot were recorded. The abiotic factors measured were elevation, topographic position, and distance to the nearest cliff. The biotic factors measured were cover type, conifer stem density, conifer canopy cover, and canopy coverage classes for total shrubs, individual shrub species, and total perennial graminoids. Methods of measurement and coverage classes were identical to those previously described for the group sighting and bedding site analysis.

Fecal pH

Within the study area, bighorn sheep and mule deer occupied overlapping winter ranges. Therefore, pellet group counts used to investigate bighorn winter range use are subject to error unless fecal groups can be reliably separated by species. Since external examination of ungulate pellets is not always a reliable method of species identification (Neff 1968), fecal pH was investigated as a possible method of differentiation in the present study (Howard 1967, Nagy and Gilbert 1968, and Krausman et al. 1974).

Fecal groups were collected from the exclusive winter ranges of mule deer and bighorn sheep. Permanent plots established and cleared in December were revisited in early April, and 50 pellet group samples collected from each range. Samples were air-dried for approximately 2 months at room temperature. Two grams of each sample were crushed with a mortar and pestle and placed in 30 ml of demineralized water and stirred vigorously. After a 10 minute soaking period, the samples were filtered through standard number 41 filter paper and the pH of the solution determined with a Corning Model 7 pH meter.

Food Habits

Fifty bighorn fecal groups were collected throughout the winter after direct observation of defecating animals. Pellet groups were air dried at room temperature for approximately 8 months. Two pellets were selected randomly from each pellet group collected to form a composite winter bighorn fecal sample. This composite sample was then crushed and mixed well. Twenty randomly selected portions of the composite sample were sent to the Composition Analysis Laboratory, Ft. Collins, Colorado, for identification and quantification of plant fragments in the feces (Sparks and Malechek 1968). Four hundred microscopic fields on a binocular microscope at 100x were examined and average percent relative densities calculated for plant species present. Research by Todd and Hansen (1973) and Dearden et al. (1975) suggests that percent relative density figures may nearly approximate the percentage dry weights in the diet.

Forage Utilization

Browse utilization for serviceberry (*Amelanchier alnifolia*), mountain maple (*Acer glabrum*), bitterbrush (*Purshia tridentata*), and chokecherry (*Prunus virginiana*) was estimated by a twig-count technique (Shafer 1963) with utilization expressed as percentage of twig numbers browsed. The term "twig" was defined as that portion of a branch developed during the last growing season (Stickney 1966). Five winter range areas were sampled with three transects each. The location of each transect was determined in a restricted random manner. The selection of sample twigs for counting purposes was similar to the method of Stickney (1966). In each 20 foot (6.1 m) section of a transect, the individual shrub of each desired species closest to the transect line but not farther than 20 feet (6.1 m), was selected as the sample plant. The major branch or stem with at least 10 twigs of current growth between 1 and 4 feet (30.5-122 cm) above the ground that was nearest the transect line was selected as the sample "twig cluster". Browsed and unbrowsed twigs within that twig cluster were then counted. If no single stem of the selected plant had the minimum 10 twigs, then the branch nearest the transect line was combined with the nearest adjacent stem or stems to constitute the sample twig cluster.

In addition, 50 sample twig clusters each of serviceberry and mountain maple were randomly selected for measurement of browsed and unbrowsed twig lengths in inches. This yielded estimates of average lengths for browsed and unbrowsed twigs. These estimates were then combined with the percentage of twig numbers browsed to estimate the percentage of available total length removed by browsing.

The degree of utilization by herbivores was also estimated for bluebunch wheatgrass, the dominant perennial graminoid on the study area. Bluebunch wheatgrass was estimated to constitute approximately 90 percent of the perennial graminoid cover on the study area. Rough fescue was locally abundant in the Munson Creek area. Pine grass (*Calomagrostis rubescens*) was found in some forest stands and elk sedge was present at higher elevations. Idaho fescue (*Festuca idahoensis*) was present but scarce on the study area.

Four winter range areas were sampled for bluebunch wheatgrass utilization with the same transects utilized in the browse utilization analysis. One bluebunch wheatgrass plant was sampled every 10 feet of transect. The plant closest to a mark on the investigator's right boot was classified as grazed or ungrazed, the height of grazed and ungrazed portions of the plant measured, and an estimate made of the percentage of the total canopy cover grazed. In addition, 15 ungrazed plants were collected and weighed in 10 percent intervals to establish a height removed/weight removed relationship for bluebunch wheatgrass on the study area. Using the method of "least squares" described by Mendenhall (1971), a linear regression line was developed for the raw data and for an appropriate transformation of the data. An estimate of utilization by weight was then computed.

Availability Sample of the Study Area

Since the study area is composed of mountainous terrain with diverse vegetation and many complicated patterns of habitat availability, a random point method of sampling was employed (Marcum 1975). The borders of the study area were selected to include only those lands that were visible from the census routes and thus were examined at least weekly for use by bighorn sheep. Utilizing the four digit location code developed for recording bighorn sheep group observations, 150 points were selected for initial sampling through the use of a random numbers table. The estimated proportion of the study area in each habitat category was then determined by locating these points on topographic maps and aerial photographs. These proportions were treated as binomial parameters and the number of points needed to estimate each habitat category to within ± 0.05 of the true proportion at the 95 percent confidence level was determined (Mendenhall 1971). Since 244 random points was the largest number required in any habitat category for the level of accuracy desired, 94 additional locations within the study area were selected from a random numbers table. The proportion of total random points (244) in each habitat category was then determined.

The distribution of points over the study area was tested for randomness by dividing the area into five subunits. The area of each subunit was then determined with a compensating polar planimeter. The proportion of the total study area occupied by each subunit was multiplied by the total number of random points in the availability sample to determine the expected number of points in each subunit if the distribution was random. A chi square test led to the conclusion that the availability sample was randomly distributed over the five subunits of the study area ($X^2 = 1.69$, tabular $X^2 = 9.49$, $p = .05$, 4 d.f.).

The accuracy of the study area availability sample was tested by comparing the random point predictions with polar planimeter measurements of three mappable habitat categories. The categories tested were elevations below 2,410 feet (735 m), elevations from 2,410 (735 m) to 2,800 feet (853 m), and areas having a slope steepness greater than 80 percent.

Data Analysis

Data obtained in conjunction with group observations, pellet plots, and bedding sites were numerically coded in the field and subsequently punched on computer cards. A DEC-10 digital computer system and the SPSS (Statistical Package for the Social Sciences) system of computer programs (Nie et al. 1975) were used for summary and analysis of the data.

The chi-square technique was used to test the hypothesis that bighorn sheep utilized habitat categories (i.e., rockland, shrubland) in exact proportion to their occurrence on the study area. If this hypothesis was rejected (p = 0.005), individual habitat categories were examined by the method of Neu et al. (1974). The term "preference" was utilized to describe a situation in which bighorn sheep use of a habitat category was significantly greater than its availability within the study area. The term "avoidance" was used to describe a situation where bighorn use was significantly less than availability. "None" was employed to denote the apparent selection behavior when use was not significantly different from availability. A significance level of 0.10 was used in constructing simultaneous confidence intervals on proportions of use in each habitat category.

To evaluate relationships between meteorological conditions and habitat use, Pearson product-moment correlation coefficients were determined for independent meteorological variables versus elevation, distance to the nearest 15-foot (4.6 m)-minimum cliff, distance to the nearest conifer, number of bighorns bedding, number of bighorns feeding, and group size. Analysis of variance (Mendenhall 1971) was utilized to compare mean values of dependent variables during varying meteorological conditions.

The thermograph records provided a method of determining when temperature inversions occurred on the winter range. A t-test was used to compare mean elevations of group observations during inversion and non-inversion conditions. Observations included in the inversion group were those that occurred when increasing temperatures were recorded from 2,700 feet (823 m) up to at least 4,300 feet (1,311 m) elevations.

CHAPTER IV

RESULTS

Existing Vegetation

Table 2 provides comparative data on vegetation for the four major cover types found on the study area. Important shrub species were those which attained a mean coverage value of 1 percent or more on at least one major plant cover type. Mean canopy coverage class values were computed by assigning each cover class a value equal to the midpoint of that class. Mean coverages were then computed for each plant species and reported as the coverage class in which they fell.

Potential Vegetation

Nine different forest habitat types and one special topo-edaphic situation (Pfister et al. 1974) were found within the study area. Some habitat types occurred as intricate mosaics of potential climax communities. These areas were mapped as "complexes" of the repeating habitat types occurring within them. Twelve unique categories were utilized for mapping purposes (Fig. 4) and are described below.

1) Rockland-scree comprises approximately 30 percent of the study area (Fig. 4). Pfister et al. (1974) described scree as

Table 2. Comparison of the four major plant cover types on the winter range.

	Plant Cover Type			
	Rockland	Shrubland-Grassland	Open Forest	Closed Forest
Conifers[a]				
Minimum stems/acre	1	1	1	120
Maximum stems/acre	74	48	155	880
Mean stems/acre	7	7	26	286
Mean basal area (ft^2/acre)	9.6	7.5	34.0	165.0
Mean distance nearest conifer (ft/m)	74/22.6	62/18.9	17/5.2	4/1.2
Grasses				
Agropyron spicatum	Trace[b]	5-25%	5-25%	1-5%
Calamagrostis rubescens	-	-	Trace	5-25%
Festuca scabrella[c]	-	1-5%	1-5%	-
Shrubs				
Acer glabrum	Trace	1-5%	1-5%	-
Amelanchier alnifolia	Trace	5-25%	1-5%	Trace
Ceonothus velutinous	Trace	1-5%	Trace	-
Chrysothamnus nauseasus	Trace	1-5%	Trace	-
Holodiscus discolor	-	Trace	-	1-5%
Mahonia repens	-	-	-	1-5%
Philadelphus lewisii	Trace	1-5%	1-5%	Trace
Physocarpus valvaceus	Trace	5-25%	1-5%	25-50%
Prunus virginiana	Trace	1-5%	1-5%	-
Purshia tridentata	Trace	1-5%	1-5%	-
Ribes spp.	Trace	Trace	Trace	-
Spirea betulifolia	-	-	-	1-5%
Symphoricarpos albus	-	-	Trace	25-50%
Total shrubs	1-5%	2-25%	5-25%	50-70%
Number plots sampled	29	120	53	23

[a]Pinus ponderosa and Pseudotsuga menziesii

[b]Less than 1 percent

[c]Festuca scabrella is found primarily in the Munson Creek area

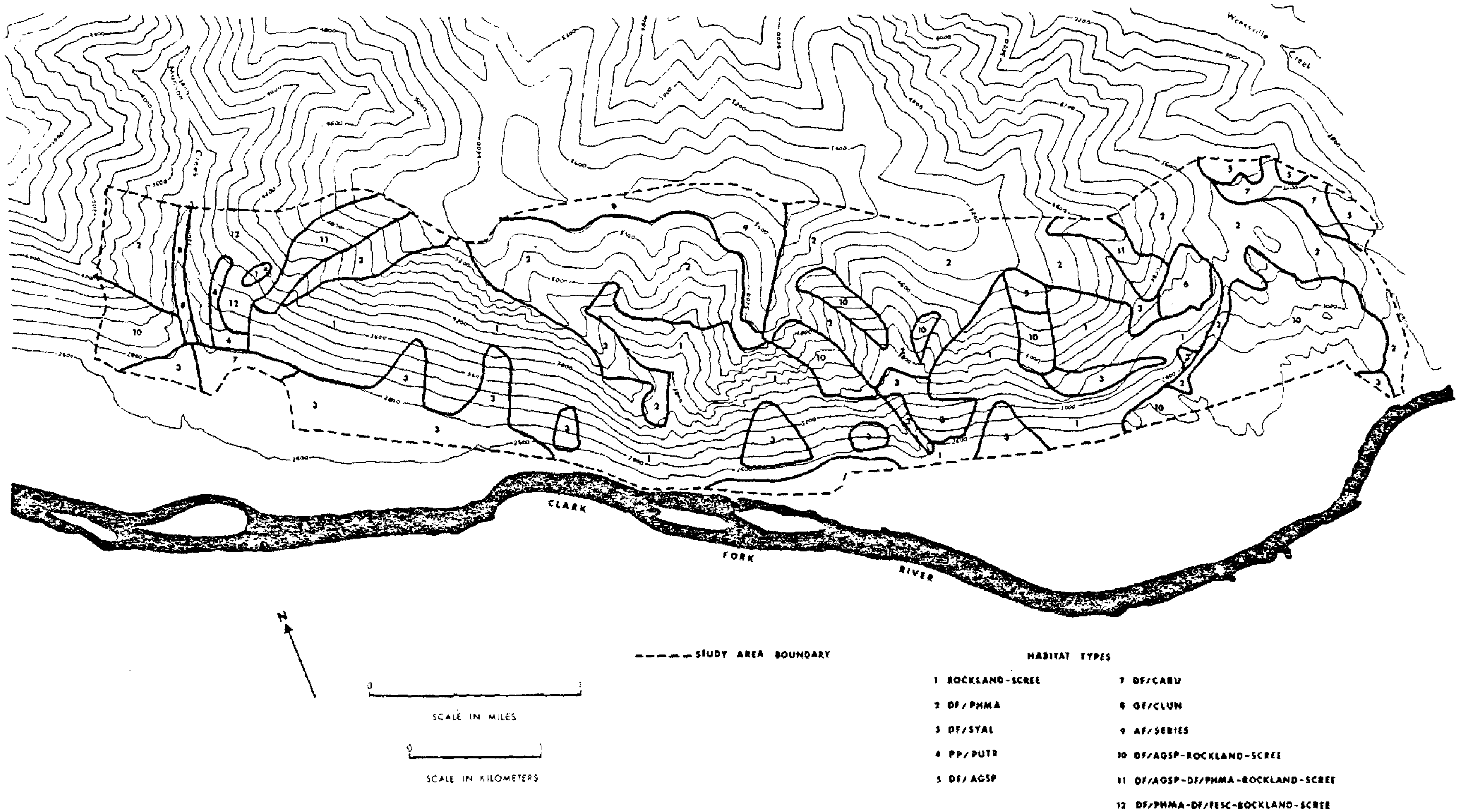

Fig. 4. Map of forest habitat types and habitat type complexes occuring on the study area.

". . . steep slopes (greater than 30 degrees) composed primarily of fine rock. Soil profile development is very weak due to the continual downslope movement of rock fragments." The study area also contains large areas of rock outcrops and stable rubble slopes that exhibit little soil development. These "rocklands" do not appear capable of supporting enough conifers to constitute the 25 percent canopy cover considered necessary by Pfister et al. (1974) for classifying a plant community as a forest. Rockland scree is not appropriately described as a forest habitat type since it represents special topo-edaphic situations that preclude development of normal successional trends (Pfister et al. 1974).

Rockland-scree occurs predominately on south to southwest slopes below 5,000 feet (1,524 m) and is vegetated primarily by the shrubland-grassland and rockland plant cover types. Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) are the dominant tree species. Serviceberry, mountain maple, ninebark (*Physocarpus malvaceus*) mockorange (*Philadelphus lewisii*), bitterbrush, chokecherry, and evergreen ceonothus (*Ceonothus velutinus*) are the most abundant shrubs. Graminoids are very poorly represented.

2) *The Douglas-fir/ninebark (DF/Phma) habitat type* is found on relatively cool and moist slopes, particularly at higher elevations (Fig. 4). Except for areas recently burned, this habitat type is generally occupied by a closed timber cover type of Douglas-fir with occasional western larch (*Larix occidentalis*) and ponderosa pine. Ninebark dominates the undergrowth at lower elevations while pine grass

and elk sedge dominate at higher elevations. Oceanspray (*Holodiscus discolor*), snowberry (*Symphoricarpos albus*), white spirea (*Spirea betulifolia*), and heartleaf arnica (*Arnica cordifolia*) are common.

3) *The Douglas fir/snowberry (DF/Syal) habitat type*, snowberry phase, is found predominately at elevations below 4,000 feet (1,219 m) on gentle to steep southerly slopes with some soil development (Fig. 4). This type often extends as forested stringers up steep rubble slopes. The DF/Syal/Syal habitat type occupies approximately 13 percent of the study area. The classification of this type was difficult on steep slopes because it was necessary to make assumptions about the climax conifer canopy cover in order to select a site representative of climax for sampling. Due to the presence of a dense overstory canopy on a stringer of DF/Syal/Syal habitat type on the study area, I assumed that a closed canopy would develop on similar sites. If a closed canopy had not been assumed, the presence of ninebark and oceonspray in canopy openings would have resulted in classification of many areas as DF/Phma, rather than DF/Syal/Syal.

Portions of this habitat type that are occupied by the closed forest cover type are dominated by medium diameter Douglas-fir. The understory is dominated by snowberry, white spirea, and Oregon grape (*Mahonia repens*). Small amounts of serviceberry, chokecherry, bluebunch wheatgrass, and pinegrass may also be present. The portions of the DF/Syal/Syal habitat type now occupied by rockland, shrubland-grassland, and open forest cover types are very different floristically and structurally from the more successionally-advanced closed-timber areas. The more open cover types commonly contain substantial amounts of bitterbrush, serviceberry, mountain maple, ninebark, and chokecherry in the shrub layer. Bluebunch wheatgrass is locally abundant. Openings containing bare rock, shrubs, and bluebunch wheatgrass are interspersed with small patches of closed forest.

4) <u>The ponderosa pine/bitterbrush habitat type</u>, Idaho fescue phase, is found on approximately 0.4 percent of the study area near the mouth of Munson Creek (Fig. 4). This habitat type occurs on a ridge and slope below 3,700 feet (1,128 m) with a southwest aspect and is now occupied by open forest and shrubland-grassland plant cover types. Ponderosa pine is the dominant conifer with Douglas-fir occurring sporadically on moist microsites. Bitterbrush is the dominant shrub and serviceberry, chokecherry, mockorange, and redstem ceonothus (*Ceonothus sanguineus*) are well represented. Idaho fescue, rough fescue, and bluebunch wheatgrass are the most abundant graminoids. Arrowlead balsamroot (*Balsamorhiza saggitata*) is the most conspicuous forb.

5) <u>The Douglas-fir/bluebunch wheatgrass (DF/Agsp) habitat type</u> represents the warm, dry extreme of the Douglas-fir climax series (Pfister et al. 1974). This habitat type occurs on the study area on southerly exposures up to approximately 5,100 feet (1,554 m) elevation (Fig. 4). The overstory is dominated by scattered, large dBH Douglas-fir and ponderosa pine. Graminoid canopy coverage is dominated by bluebunch wheatgrass. Bitterbrush, mockorange, serviceberry, mountain maple, chokecherry, currant (*Ribes* spp.), oceanspray,

arrowleaf balsamroot, and yarrow (Achillea millefolium) are often present. The DF/Agsp habitat type on the study area is presently occupied by the shrubland-grassland and open forest plant cover types.

6) The Douglas-fir/white spirea (DF/Spbe) habitat type covers approximately 0.4 percent of the study area. This habitat type occurs on a relatively gentle middle-slope area near Weeksville Creek (Fig. 4) and is currently occupied primarily by the closed timber cover type. A small portion of the area has been disturbed by logging. Douglas-fir dominates the overstory with occasional ponderosa pine present. White spirea dominates the understory. Pinegrass and elk sedge are often present.

7) The Douglas-fir/pinegrass (DF/Caru) habitat type, kinnikinnick (Arctostaphylos uva-ursi) phase, comprises approximately 1.2 percent of the study area. A closed forest cover type dominated by ponderosa pine with ponderosa pine and Douglas-fir seedlings present occupies this type. Pinegrass is the most abundant understory species, with white spirea, chokecherry, snowberry, and kinnikinnick present.

8) The grand fir/queencup beadlilly (GF/Clun) habitat type, queencup beadlilly phase, occupies a small portion of the study area (0.8 percent) immediately adjacent to Munson Creek (Fig. 4). This habitat type is occupied by a closed forest cover type dominated by Douglas-fir with grand fir and western larch also present. Western red cedar and ponderosa pine appear occassionally on extremely wet or dry sites, respectively. Twinflower (Linnaea borealis), snowberry, and white spirea are common shrubs in this type. Sweetscented bedstraw

(Galium triflorum), heartleaf arnica, starry Solomon's seal (Smilacina stellata), and pinegrass also occur in the understory.

9) The alpine fir (Abies lasiocarpa) series of habitat types is represented on approximately 3.7 percent of the study area (Fig. 4). The potential understory dominant is difficult to determine because the area burned in 1945 and no old growth stands are present. Young Douglas-fir are the most abundant trees with evergreen ceonothus, serviceberry, and buffalo berry (Shepherdia canadensis) the dominant shrubs. Pinegrass and kinnikinnick dominate the ground cover. The alpine fir series is found above 5,200 feet (1,585 m) elevation. Climatically this series is characteristic of areas having cold, snowy, continental climates (Pfister et al. 1974).

10) The DF/Agsp-Rockland-Scree complex occurs on steep, southerly slopes below 5,100 feet (1,554 m) elevation (Fig. 4). The DF/Agsp habitat type constitutes approximately 75 percent of the complex while rockland-scree makes up the remaining 25 percent. Plant species present are those characteristic of the previously described individual units of the complex.

11) The DF/Agsp-DF/Phma-Rockland-Scree complex is found on approximately 1.6 percent of the study area. The three individual units of the complex cover approximately equal areas. The plant species present are those characteristic of the previously described individual units of the complex.

12) The DF/Phma-Rockland-Scree-Douglas-fir/Rough fescue (DF/Fesc) complex accounts for approximately 3 percent of the study area (Fig. 4).

The three individual units of the complex cover approximately equal areas. The plant species present on the DF/Phma and rockland-scree portions of the complex are those previously described as characteristic of these types. The DF/Fesc habitat type overstory on the study area consists of large diameter Douglas-fir and ponderosa pine. Rough fescue dominates the graminoid cover with bluebunch wheatgrass, prairie junegrass (Koleria cristata), and idaho fescue also present. Yarrow and arrowleaf balsamroot are conspicuous forbs. Shrubs include bitterbrush, serviceberry, chokecherry, redstem ceonothus, mountain maple, and ninebark.

Trapping

Trapping activities resulted in the capture of two bighorn sheep on 14 July and five on 26 July 1975 (Table 3). Body weights were not obtained for the animals captured on 26 July as they were released immediately after the marking collars and eartags were in place. The ambient temperature was above 95° F (35° C) and I felt capture stress should be minimized.

Group Size and Age-Sex Composition

Between 1 January and 30 March 1976, 197 bighorn sheep groups were observed, accounting for 1,103 sheep-observations (Fig. 5). Mean group size was 5.6. Maximum, minimum, and mean group sizes for ewe-juvenile, young ram, adult ram, and ewe-adult ram groups are listed in Table 4. A t-test established a significant ($p = .05$) difference in mean sizes of adult ram and ewe-juvenile groups. All of the ewe-

Table 3. Age, sex, live weight, reproductive status of females, date of capture, and marking system for seven bighorn sheep captured during summer 1975.

Collar[a]							
Pendant	Flagging	Ear Tags	Capture Date	Sex	Reprod. Status[b]	Age	Weight
113 bl.	RBGG/y	A0530 A0531	7-14-75	F	NL	1	115
31 br.	GBRG/w	A0532 A0533	7-14-75	M	-	1	100
112 bl.	RRWG/y	A0534 A0535	7-26-75	F	NL	1	-
27 br.	RBRG/w	A0537 A0538	7-26-75	M	-	Lamb	-
111 bl.	GGWW/y	A0541 A0542	7-26-75	F	L	2	-
109 bl.	RGGR/y	A0544 A0545	7-26-77	F	L	4	-
117 bl.	RWGG/y	A0576 A0577	7-26-75	F	NL	4	-

[a]Color codes are as follows:

bl. - black pendant	W - white flag
br. - brown pendant	R - red flag
w - white rope	B - blue flag
y - yellow rope	G - green flag

[b]NL - non-lactating
L - lactating

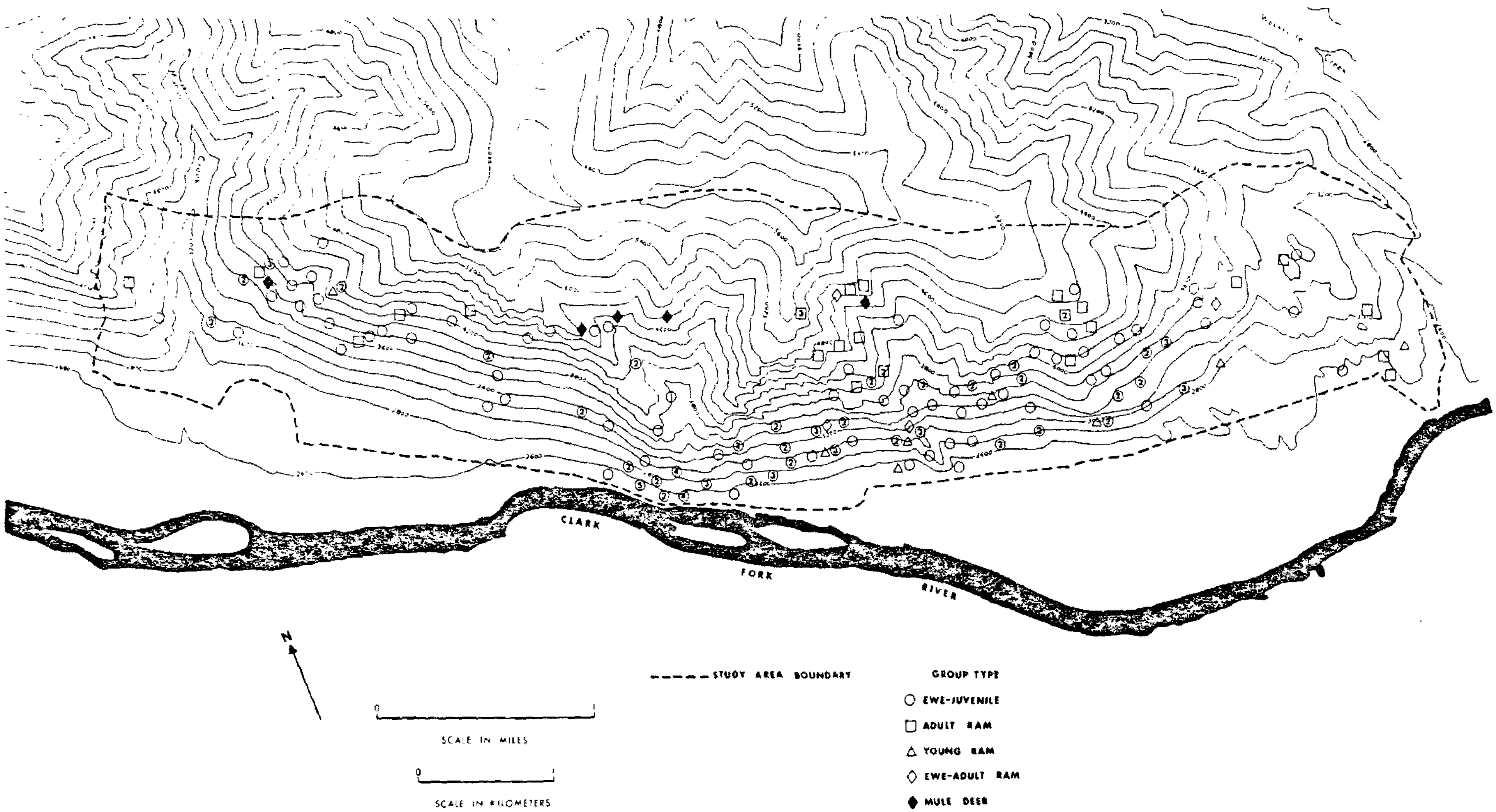

Fig. 5. Locations of bighorn sheep and mule deer groups observed between 1 January and 30 March 1976 (numbers indicate multiple observations).

Table 4. Minimum, maximum, and mean group size of bighorn sheep on winter range.

Group Type	No. Groups Observed	Group Size Minimum	Maximum	Mean
Ewe-Juvenile	158	1.0	18.0	5.4
Young Ram	8	1.0	4.0	2.1
Adult Ram	27	1.0	16.0	7.0
Ewe-Adult Ram	4	2	20	10.3
All Categories	197	1.0	18.0	5.6

adult ram groups were observed on or before 20 January 1976. The largest ram group was observed on 19 January and consisted of 12 males with horns 3/4 curl or longer, 2 males with horns 1/2 to 3/4 curl, and 2 male yearlings. The largest ewe-juvenile group was observed on 2 March and consisted of 6 lambs, 2 male yearlings, and 10 adult ewes (includes female yearlings).

All animals present were classified according to sex and age in 149 of the bighorn sheep group observations (Table 5). To eliminate possible bias, the groups that were not entirely classified were excluded from the age and sex composition analysis.

Movements and Home Range

Standard diameters (Table 6) and minimum home range sizes (Table 7) were calculated for nine marked bighorns. The female yearling was observed three times during the winter. All other marked animals reported were observed a minimum of four times each during the winter. Eleven observations of an adult ewe was the maximum number of resightings. Minimum home ranges of two adult males are illustrated in Fig. 6. Figs. 7 and 8 illustrate minimum home ranges of two adult females. The minimum home range of a male yearling is illustrated in Fig. 9.

Availability Sample of the Study Area

The accuracy of the study area availability sample was tested by comparing the random point predictions with polar planimeter measurements of three mappable habitat categories. Results of this

Table 5. Sex and age classification of bighorn sheep on winter range[a].

	Number Observed	Calculated Number: 100 Adult Ewes[b]
Lambs	241	92
Yearling Male	54	21
Young Ram ($\geq$ 1/2 $<$ 3/4 Curl)	79	30
Adult Ram ($\geq$ 3/4 Curl)	99	38
Adult Females and Yearling Females	317	-
Yearling Females	-	21
Total Yearlings	-	42
Total Males ($\geq$ 1/2 Curl)	178	68
Sample Size	790	

[a]Data includes only those group observations in which all animals were classified.

[b]Yearling females were assumed to equal yearling males, hence corrected adult females = 263.

Table 6. Activity ranges of marked bighorn sheep during winter as determined by standard diameters.

Classification	Mean Std. Dia. mi/km	Sample Size	Range of Individual Std. Dia. mi/km
Lamb	2.60/4.18	1	-
Male Yearling	4.65/7.48	1	-
Female Yearling	5.88/9.46	1	-
Adult Female	2.63/4.23	4	1.55-3.95/2.49-6.35
Adult Males	1.89/3.04	2	.67-3.10/1.07-4.98

Table 7. Minimum home ranges of marked bighorn sheep during winter.

Classification	Mean Size ac/ha	Sample Size	Range ac/ha
Lamb	139/56.2	1	-
Male Yearling	726/243.8	1	-
Female Yearling	114/46.1	1	-
Adult Female	320/129.5	4	30-923/12.1-373.5
Adult Male	271/109.6	2	56-486/22.6-196.6

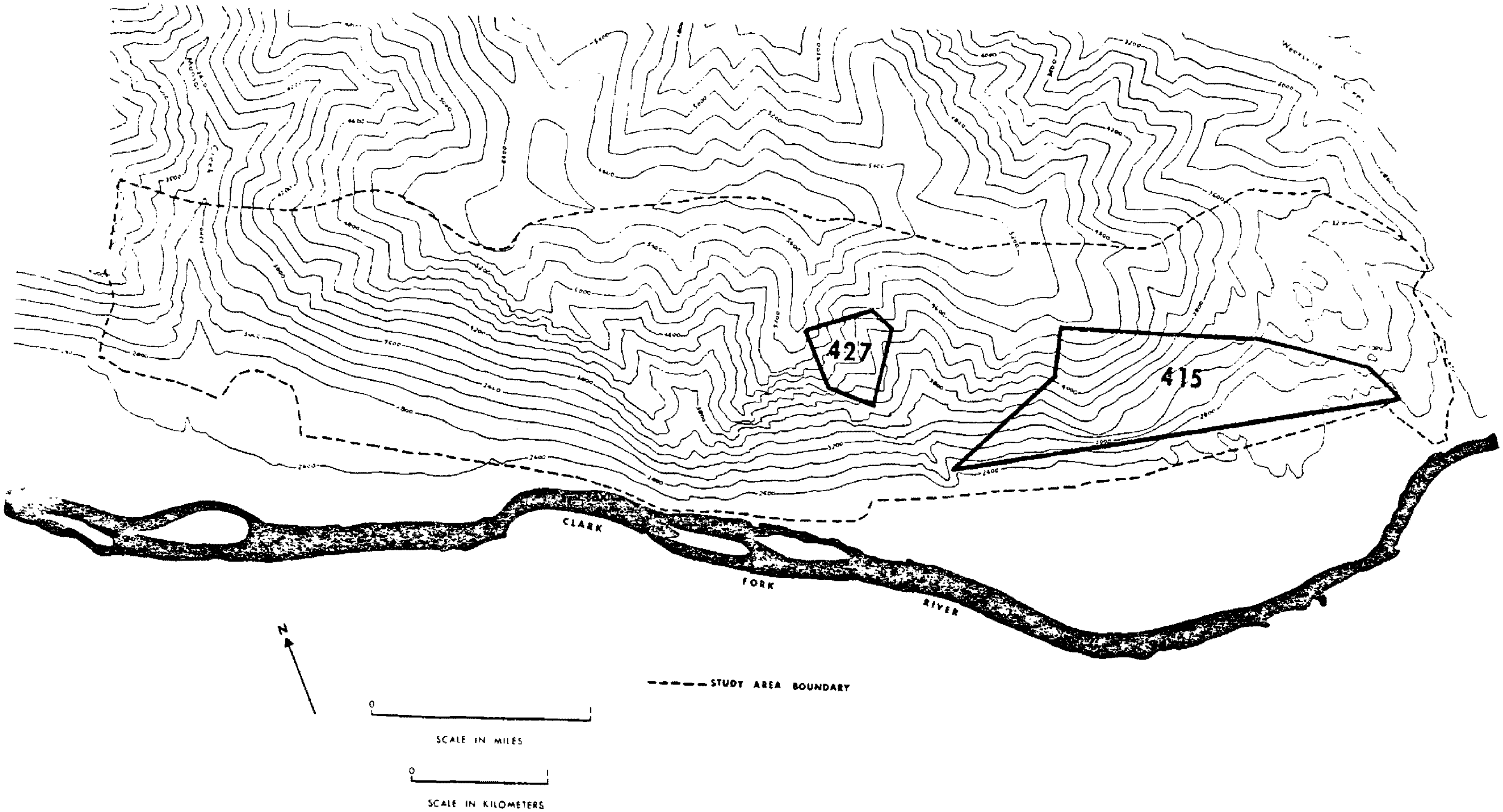

Fig. 6. Minimum winter home ranges of adult males Nos. 415 and 427, measuring 490 acres (198 ha) and 56 acres (23 ha), respectively.

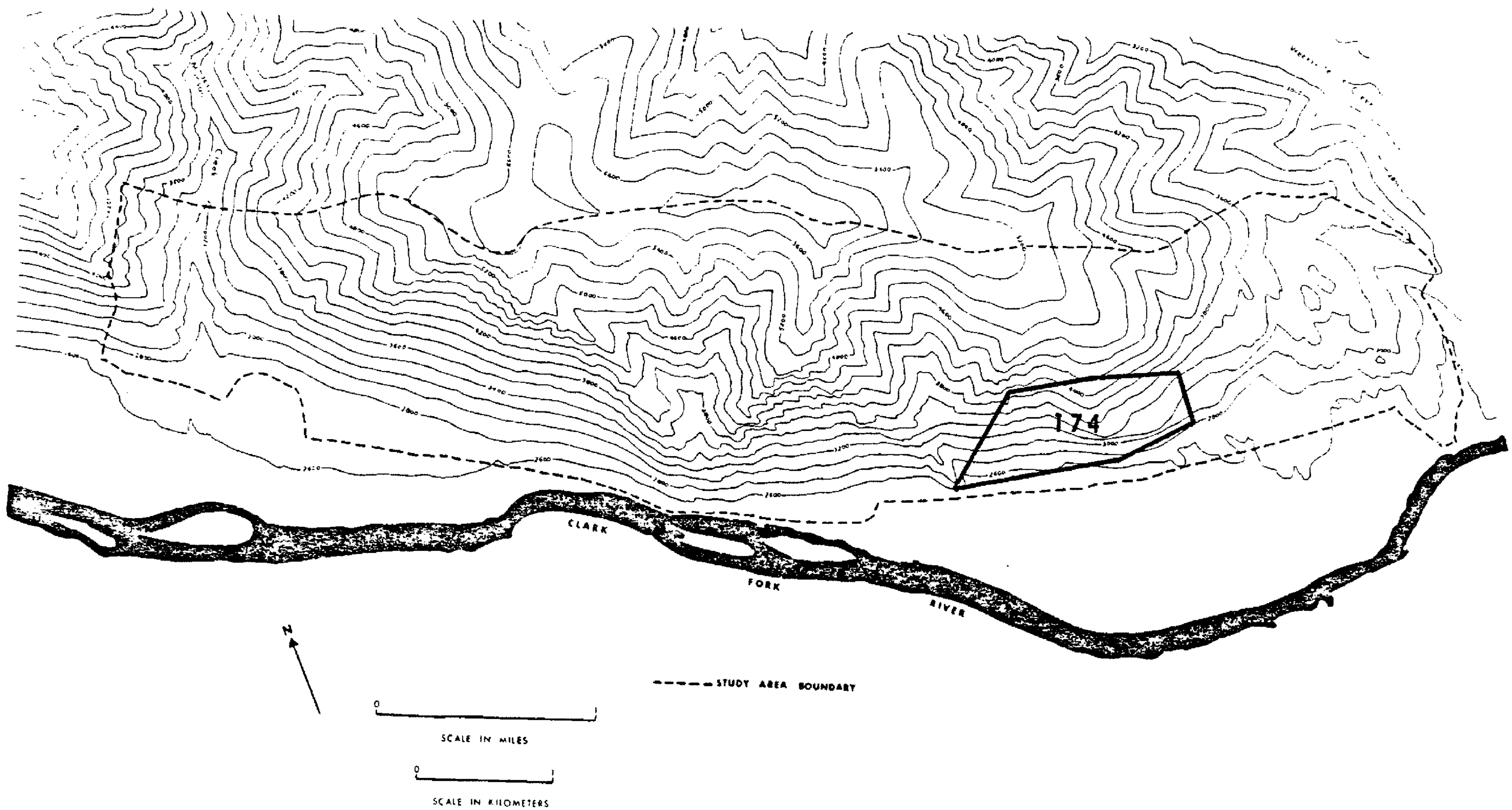

Fig. 7. Minimum winter home range of adult female No. 174, measuring 181 acres (73 ha).

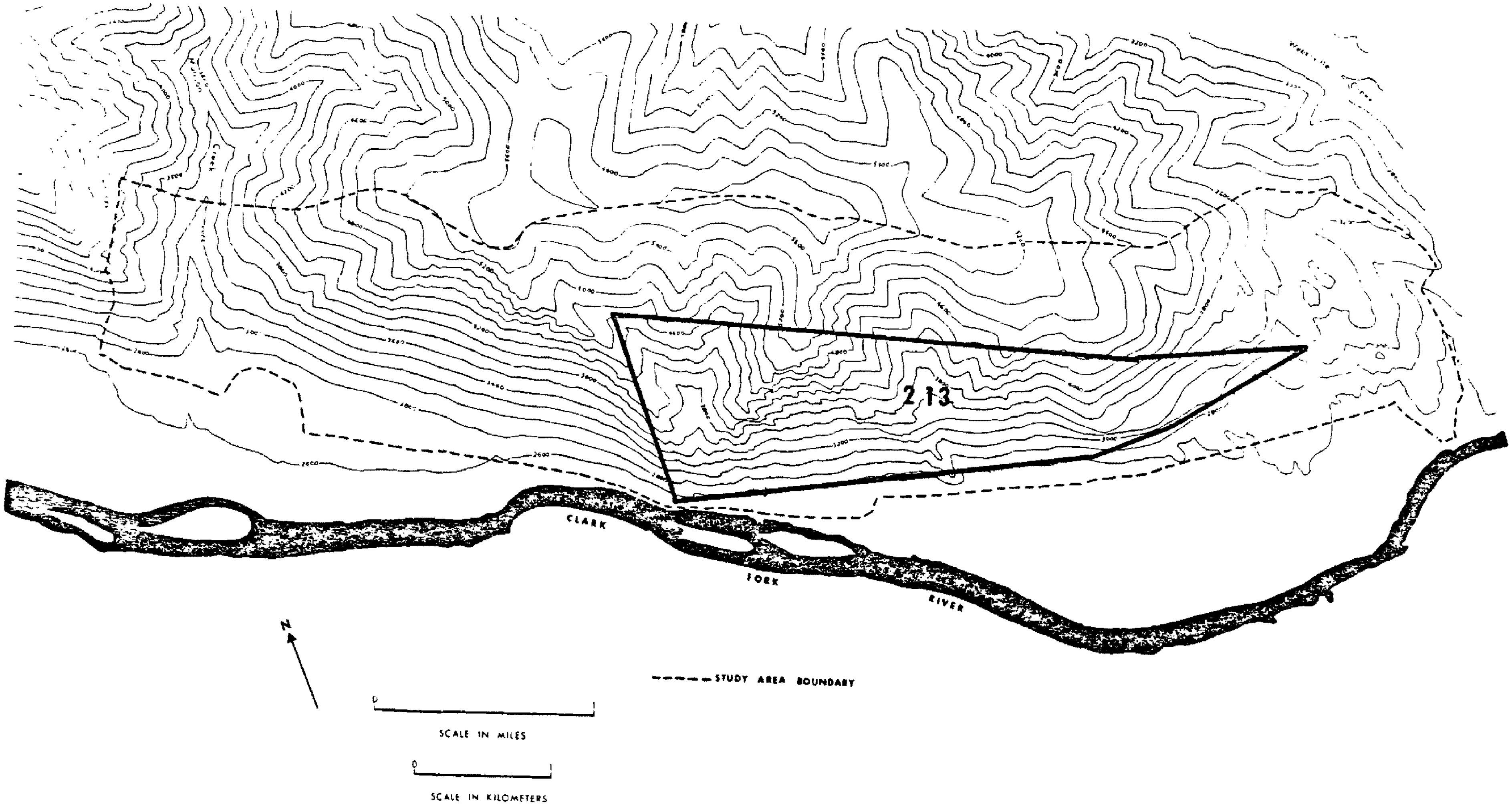

Fig. 8. Minimum winter home range of adult female No. 213, measuring 920 acres (372 ha).

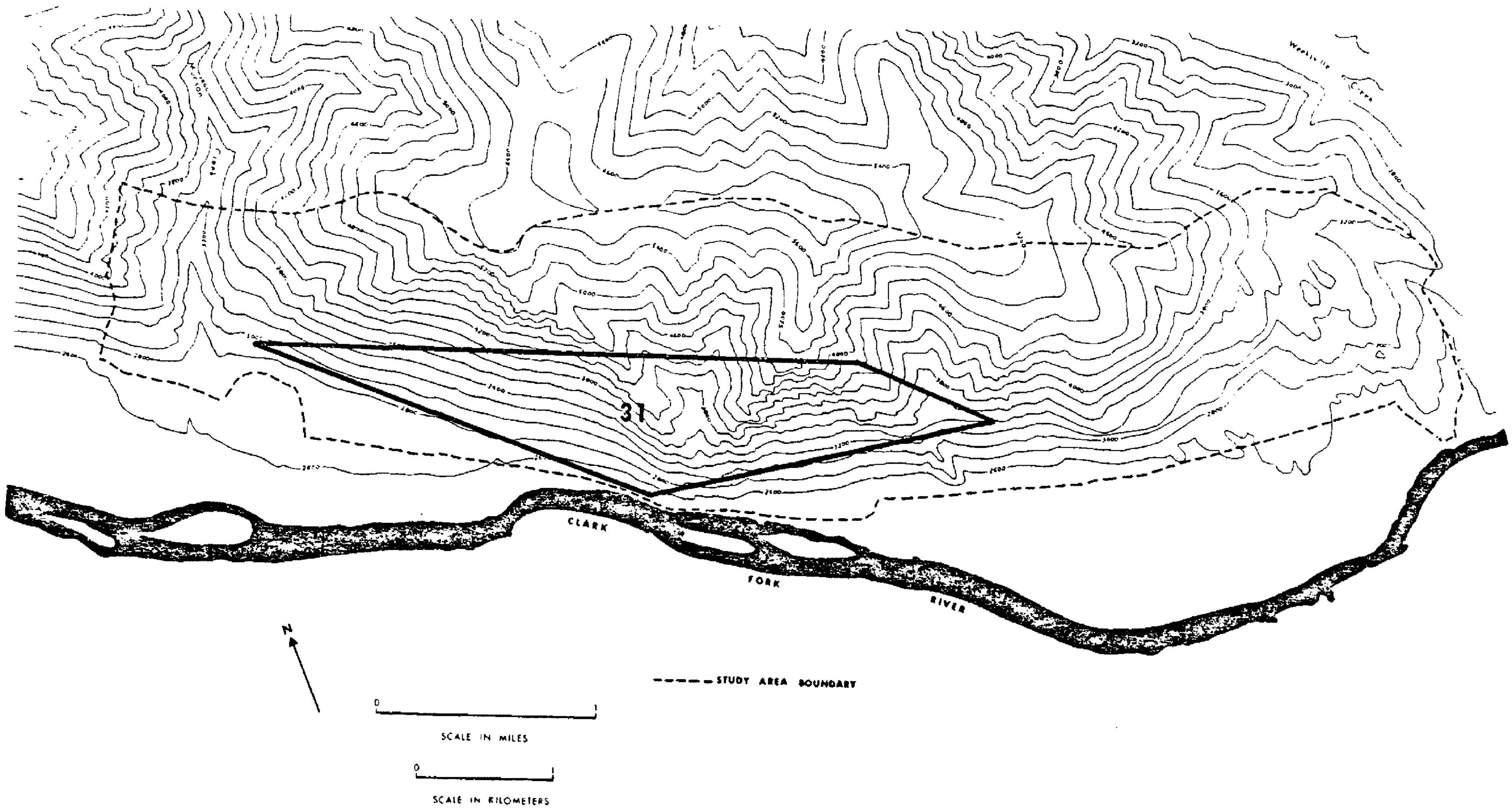

Fig. 9. Minimum winter home range of yearling male No. 31, measuring 717 acres (290 ha).

comparison are given in Table 8. There was no significant difference ($p = 0.05$) between the acreages as measured and the acreages as predicted by the random point data.

Habitat Selection and Use

Chi-square goodness of fit tests established that the seven general habitat factors tested were not used in proportion to their occurrence on the study area ($p = 0.005$).

Elevation. Elevations below 4,800 feet (1,463 m) were used in approximately the same proportion as their availability (Table 9). Elevations above 4,800 feet (1,463 m) were avoided. Percentages of bedding and feeding at various elevations are shown in Fig. 10. The percentages of each activity were nearly equal at all elevations.

Topographic position. Wintering bighorns on the study area avoided drainage bottoms and upper slopes (Table 10). Cliffy areas were preferred while lower slopes, middle slopes, and ridges were used in proportion to their availability. Percentages of bedding and feeding sites on various topographic positions are shown in Fig. 11. Middle and lower slopes received the highest percentages of feeding activities. Percentages of bedding activities were highest on middle slopes and cliffs.

Slope steepness. Areas with a slope steepness of 10-35 percent were avoided by bighorn sheep (Table 11). Areas with a slope steepness greater than 80 percent were preferred. Feeding activities were

Table 8. Comparison of areas measured with polar planimeter versus areas predicted by random point sample.

Habitat factor	Measured		Random point Prediction		Chi^2
	%	acres	%	acres	
$\leq$ 2800 ft. elev.	16.1	659	16.8	689	1.31
2810-3200 ft. elev.	15.5	638	15.0	615	.86
slope $>$ 80 percent	8.9	367	8.2	336	2.86
				Total x^2 =	5.03[a]

[a]Table x^2 = 5.99, p = .05, 2 d.f.

Table 9. Total bighorn sheep use at various elevations compared to availability of those elevations on the winter range.

Elevation (feet above sea level)	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
2800	690/279	.168	.234	46	33.1	.159 Po .263	None
2810-3200	616/249	.150	.193	38	29.6	.123 Po .263	None
3210-3600	677/274	.165	.223	44	32.5	.149 Po .297	None
3610-4000	468/189	.114	.173	34	22.5	.106 Po .240	None
4010-4400	456/185	.111	.086	17	21.9	.036 Po .136	None
4410-4800	403/163	.098	.066	13	19.3	.022 Po .110	None
4810	792/321	.193	.025	5	38.0	.000 Po .053	Avoidance
Totals	4102/1660			197	196.9		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .168 x 197 = 33.1

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

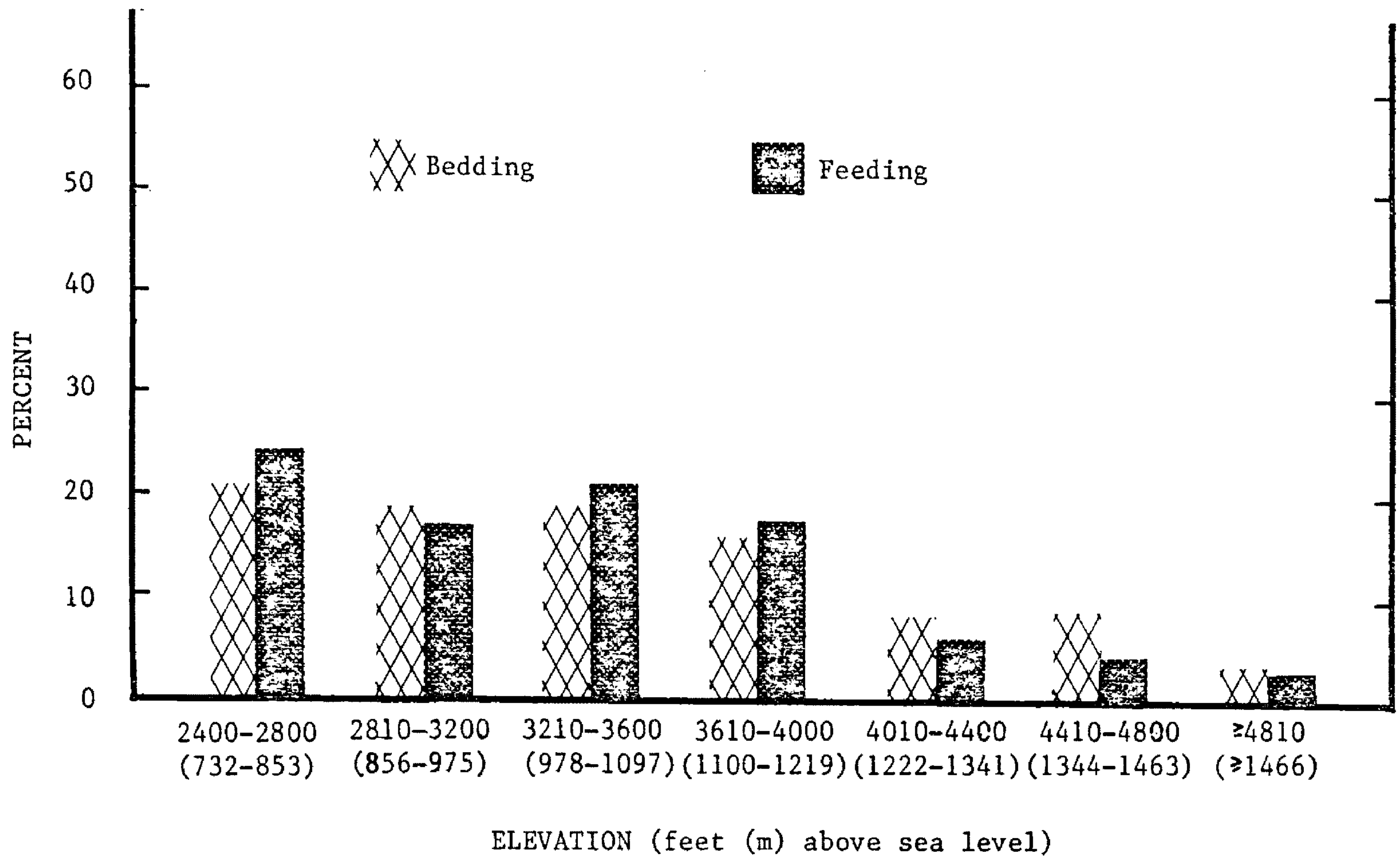

Fig. 10. Percentages of bighorn sheep group bedding and feeding sites at various elevations.

Table 10. Total bighorn sheep use on topographic position categories compared to availability of those categories on the winter range.

Topographic position	Total acreage estimate	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
Drainage bottom	370/150	.090	.010	2	17.7	.000 Po .027	Avoidance
Lower slope	1108/448	.270	.218	43	53.2	.147 Po .289	None
Middle slope	1026/415	.250	.330	65	49.3	.249 Po .411	None
Upper slope	1043/422	.254	.122	24	50.0	.066 Po .178	Avoidance
Ridge	403/163	.098	.127	25	19.3	.052 Po .202	None
Cliff	152/62	.037	.193	38	7.3	.125 Po .261	Preference
Totals	4102/1660			197	196.8		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat category in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .090 x 197 = 18.

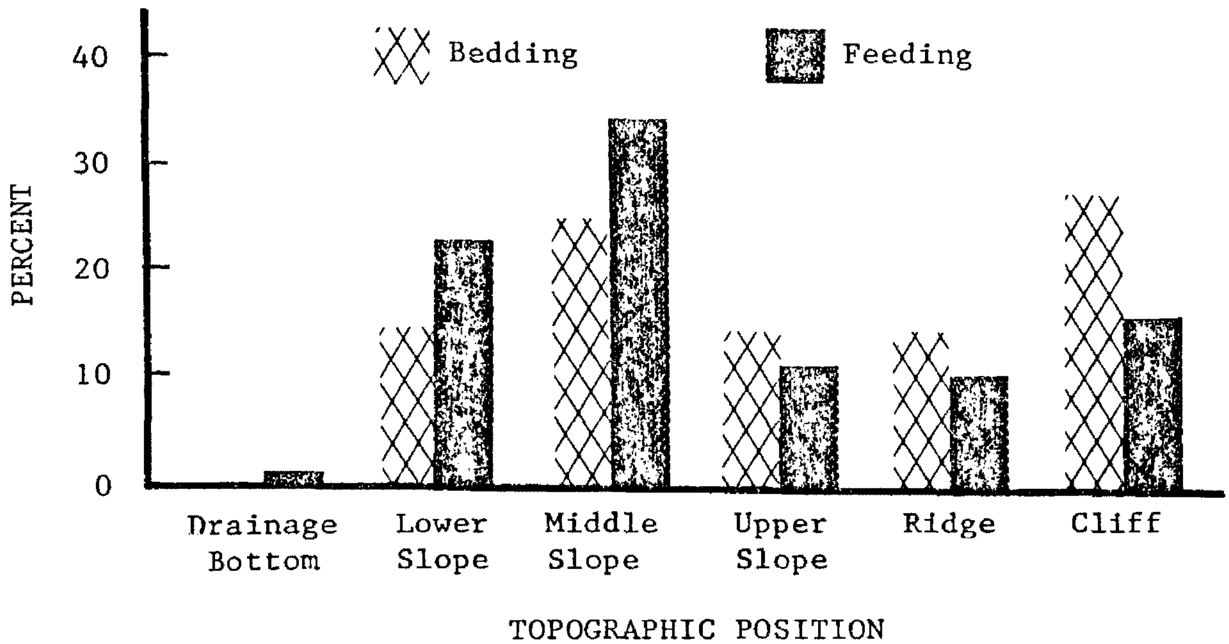

Fig. 11. Percentages of bighorn sheep group bedding and feeding sites on various topographic positions.

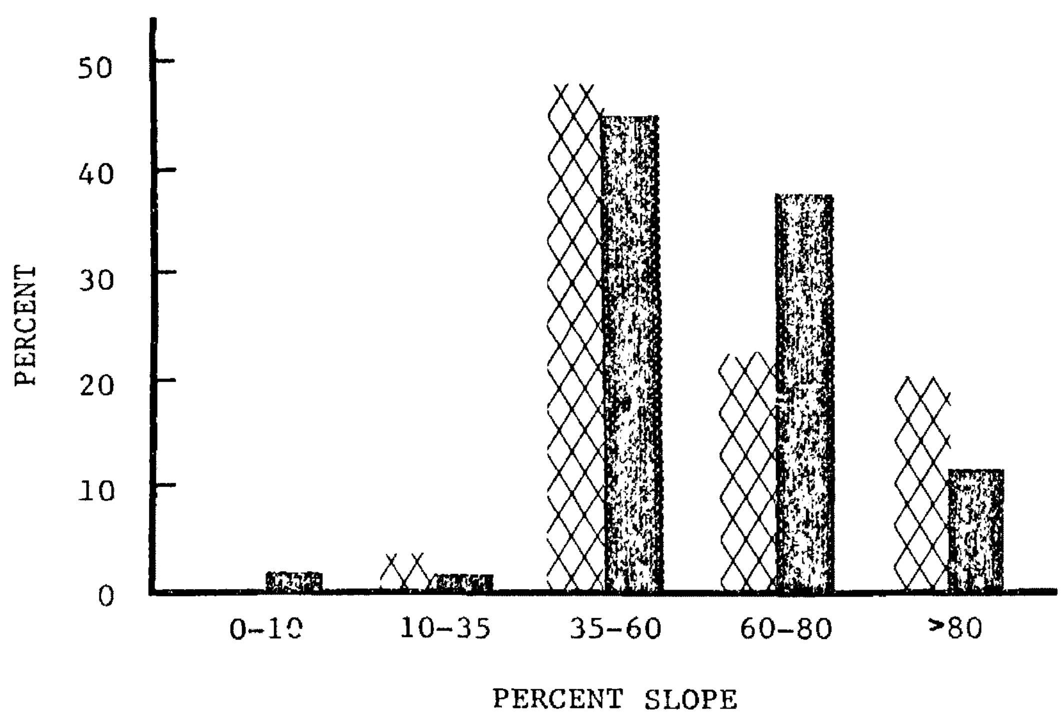

Fig. 12. Percentages of bighorn sheep group bedding and feeding sites on various degrees of slope steepness.

Table 11. Total bighorn sheep use on various categories of slope steepness compared to availability of those categories on the winter range.

Slope steepness (percent)	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
0-10	66/27	.016	.015	3	3.1	.000-.035	None
10-35	755/306	.184	.036	7	36.2	.005-.067	Avoidance
35-60	1817/735	.443	.467	92	87.3	.384-.550	None
60-80	1144/463	.279	.345	68	55.0	.266-.424	None
80	320/129	.078	.137	27	15.4	.080-.194	Preference
Totals	4102/1660			197	197		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .016 x 197 = 3.1

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

concentrated on areas of 35-80 percent slope (Fig. 12). The highest percentage of bedding activities was on 35-60 percent slopes.

Aspects. East and southeast aspects were avoided during the winter (Table 12). South aspects were preferred while no selection behavior was apparent for other aspects. Feeding and bedding site percentage of bedding was over twice the percentage of feeding on west slopes. Northwest, north, northeast, and east slopes received light feeding use and no bedding use (Fig. 13).

Distance from steep terrain. Areas within 0.2 mile (322 m) of a steep terrain area greater than 4 acres (1.6 ha) with greater than 80 percent slope were preferred (Table 13). Areas farther than 0.20 mile (322 m) from steep terrain were avoided. Percentages of bedding and feeding at various distances from steep terrain were nearly equal (Fig. 14).

Plant cover type. Shrubland-grassland and open forest plant cover types were preferred by bighorn sheep during winter (Table 14). Closed forest was avoided and rockland was used in proportion to its availability on the study area. The percentage of bedding sites on rockland was nearly three times the percentage of feeding sites (Fig. 15). The percentage of feeding sites in open forest was substantially higher than the percentage of bedding sites. Percentages of total use on areas of 0-24, 25-75, and 76-100 percent coniferous canopy cover were 59, 40, and 1, respectively.

Table 12. Total bighorn sheep use on various aspects compared to availability of those aspects on the winter range.

Aspect	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed[b]	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
Northwest, North, and Northeast	49/20	.012	.005	1	2.4	0.00 Po .017	None
East	336/136	.082	.015	3	16.2	0.00 Po .036	Avoidance
Southeast	673/272	.164	.066	13	32.3	.023 Po .109	Avoidance
South	1026/415	.250	.503	99	49.2	.417 Po .589	Preference
Southwest	1665/674	.406	.330	65	80.0	.249 Po .411	None
West	353/143	.086	.081	16	16.9	.034 Po .128	None
Total	4102/1660			197	197.0		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat category in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .012 x 197 = 2.4.

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

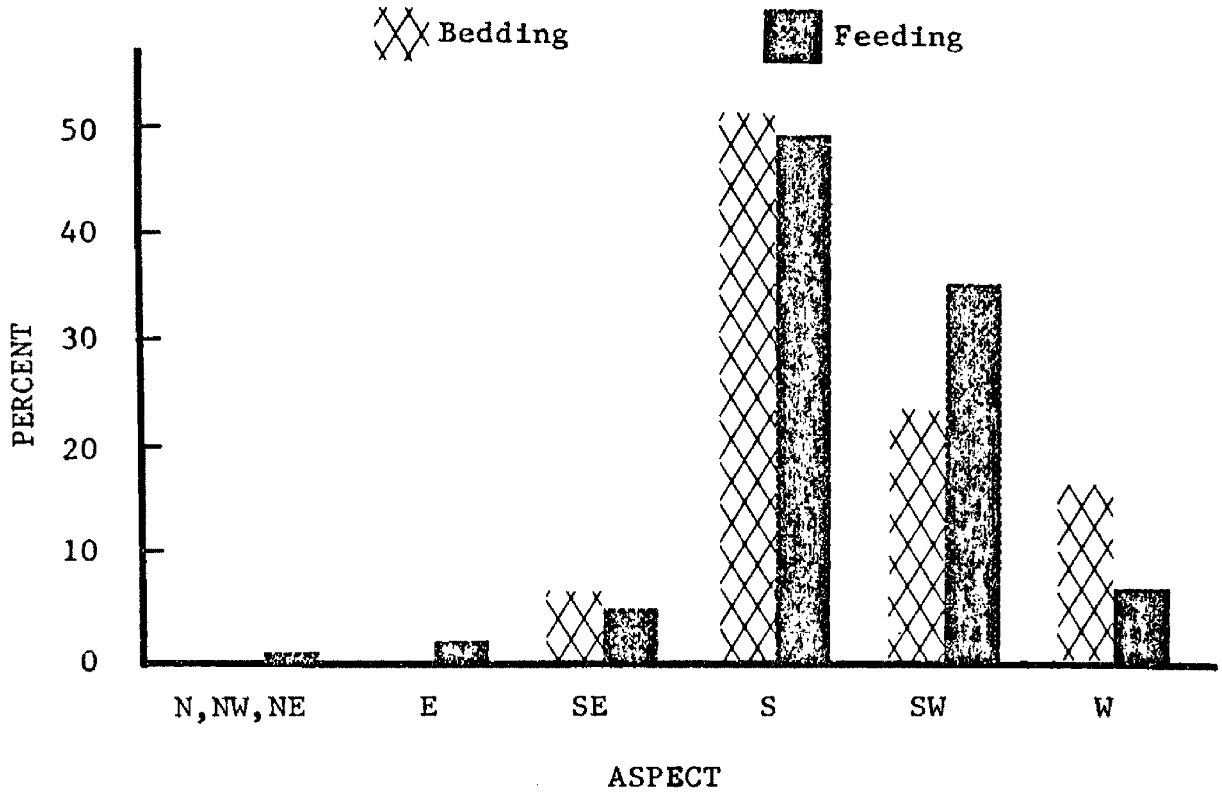

Fig. 13. Percentages of bighorn sheep group bedding and feeding sites on various aspects.

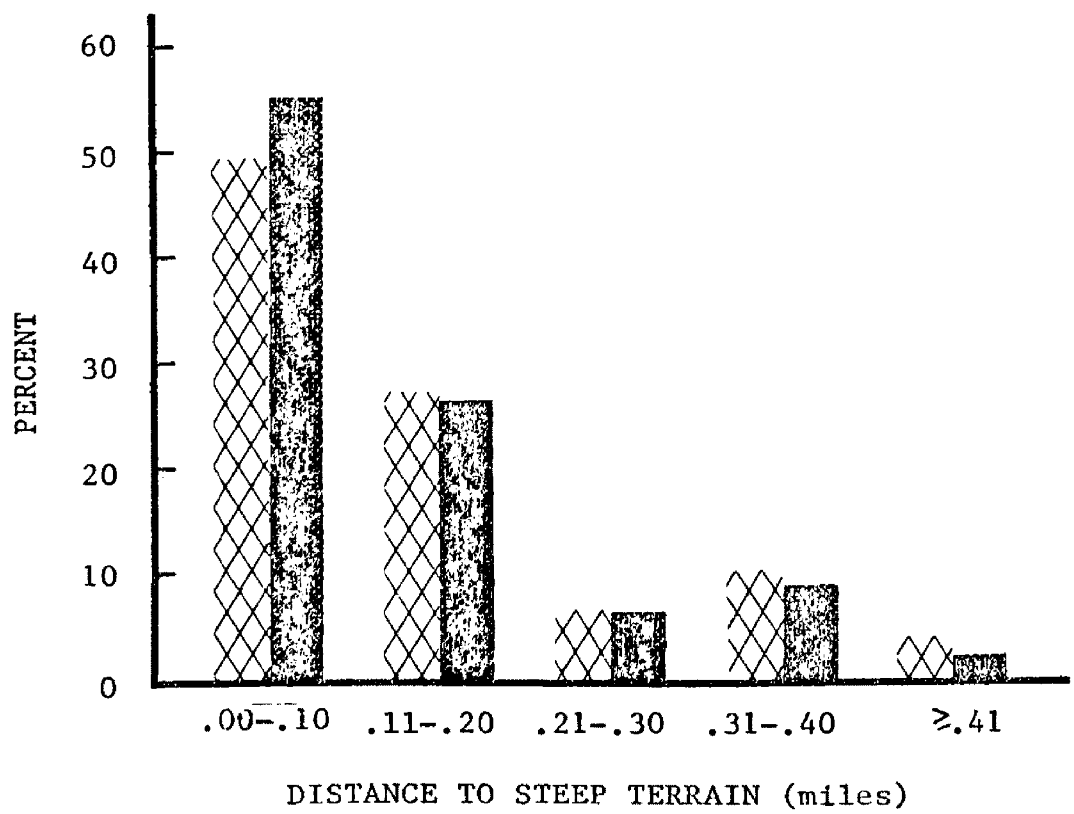

Fig. 14. Percentages of bighorn sheep group bedding and feeding sites at various distances to steep terrain.

Table 13. Total bighorn sheep use at various distances from steep terrain compared to availability of areas at those distances on the winter range.

Distance from steep terrain (miles)	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
0-.10 (0-.16 km)	1329/538	.324	.558	110	63.8	.475 Po .641	Preference
.11-.20 (.18-.32 km)	624/253	.152	.259	51	29.9	.186 Po .332	Preference
.21-.30 (.34-.48 km)	722/292	.176	.066	13	34.7	.025 Po .107	Avoidance
.31-.40 (.50-.64 km)	656/265	.160	.086	17	31.5	.039 Po .133	Avoidance
.41 (.66 km)	771/312	.188	.030	6	37.0	.002 Po .058	Avoidance
Total	4102/1660			197	196.9		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .324 x 197 = 63.8.

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

Table 14. Total bighorn sheep use on various plant cover types compared to availability of those types on the winter range.

Plant cover type	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
Rockland	554/225	.135	.137	27	26.6	.082 Po .192	None
Shrubland and Shrubland-Grassland	1296/524	.316	.457	90	62.3	.377 Po .537	Preference
Open Forest	1058/428	.258	.396	78	50.8	.318 Po .474	Preference
Closed Forest	1194/483	.291	.010	2	57.3	.000 Po .026	Avoidance
Total	4102/1660			197	197.0		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .135 x 197 = 26.6.

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

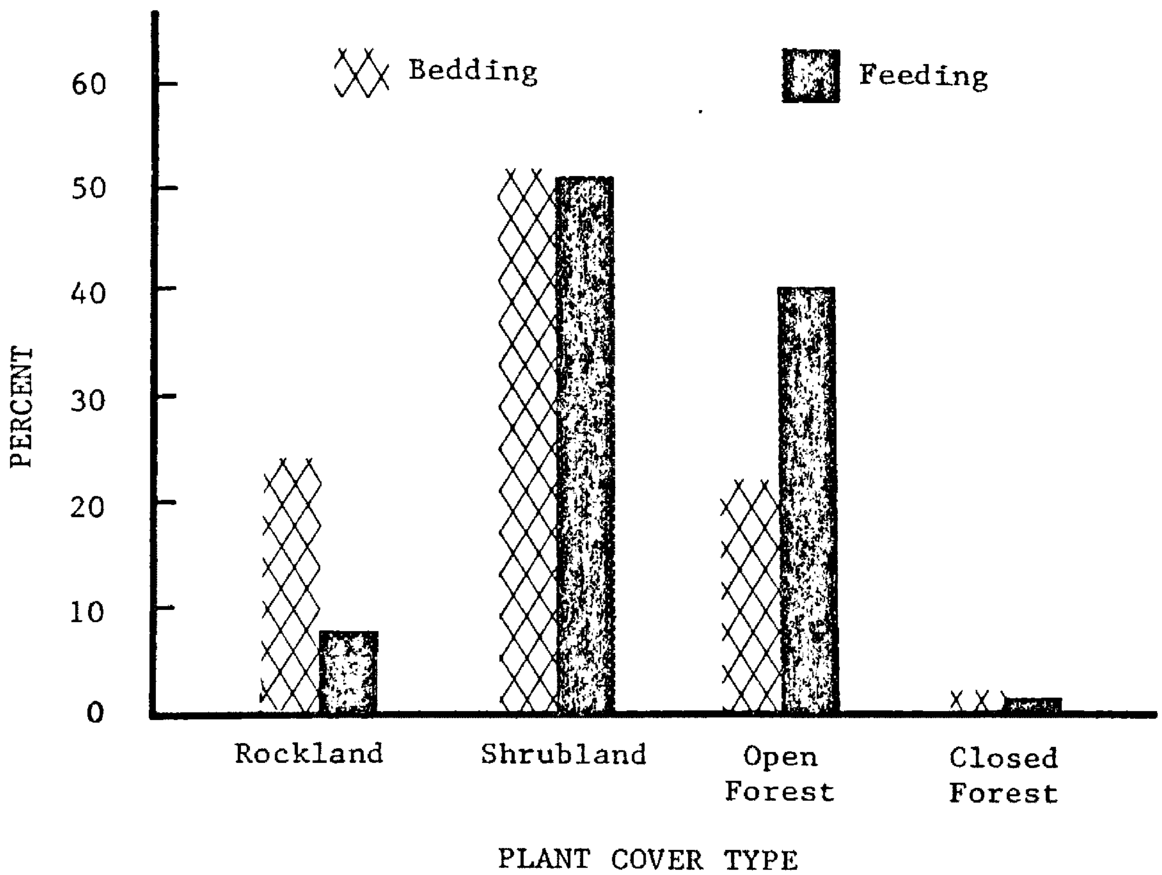

Fig. 15. Percentages of bighorn sheep group bedding and feeding sites in various plant cover types.

Habitat type. The rockland and scree habitat type classification was preferred by wintering bighorn sheep (Table 15). The DF/Phma habitat type was avoided. Percentages of bedding and feeding sites occurring on various habitat types is shown in Fig. 16. Rockland and scree and the DF/Syal/Syal types received the highest percentages of feeding use. The highest percentages of bedding activities were on rockland and scree and DF/Agsp-rockland and scree habitat types.

Comparison of Habitat Use by Group Types

Use of various habitat factors by young ram, adult ram, and ewe-juvenile groups is compared in Table 16. T-test results indicated adult ram groups were observed at a significantly (0.001) higher mean elevation than young ram or ewe-juvenile groups. Eighty-one percent of the adult ram groups were observed above 3,600 feet (1,097 m) elevation while 72.1 percent of ewe-juvenile observations were below 3,600 feet (1,097 m) (Table 16). There was a significant (0.01) difference in mean distance to the nearest 15-foot-minimum (4.6 m) cliff, adult ram groups occurring, closer than ewe-juvenile or young ram groups. In contrast, adult ram and ewe-juvenile groups were sighted in areas more than 0.3 miles (483 m) from steep terrain ($>$ 80 percent slope, 4 ac (1.6 ha) minimum size) 22.2 and 8.9 percent of the time, respectively. Adult ram groups utilized ridges and upper slopes a greater percentage of the time than young ram or ewe-juvenile groups did. The DF/Agsp-rockland and scree habitat type complex was used a much greater percentage of the time by adult ram groups than other group types were.

Table 15. Total bighorn sheep use on various forest habitat types compared to availability of those types on the winter range.

Forest habitat types	Total acreage estimate ac/ha	Proportion of study area in each category[a] (Pa)	Proportion of group observations in each category (Po)	Number of groups observed	Expected number of groups observed[b]	Confidence interval on proportion of group observations (90% family confidence coefficient)	Apparent selection behavior[c]
Rockland and Scree	1243/503	.303	.492	97	59.7	.402-.582	Preference
DF/Agsp-Rockland and Scree	472/191	.115	.178	35	22.7	.109-.247	None
DF/Agsp-DF/Phma-Rockland and Scree	66/27	.016	.025	5	3.2	.000-.053	None
DF/Phma-DF/fesc-Rockland and Scree	120/48	.029	.030	6	5.7	.000-.061	None
DF/Syal/Syal	538/218	.131	.162	32	25.8	.096-.228	None
DF/Phma	1346/545	.328	.081	16	64.6	.032-.130	Avoidance
PP/Putr	17/7	.004	.020	4	0.8	.000-.045	None
All other types[d]	300/121	.073	.01	2	14.4	.000-.028	Avoidance
Total	4102/1660			197	196.9		

[a]Proportions of total study area represent expected bighorn sheep group observation values as if bighorn sheep occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion Pa x (total number of group observations); i.e., .303 x 197 = 59.7.

[c]Pa confidence interval on Po = Preference; Pa confidence interval on Po = Avoidance; Pa within confidence interval on Po = None.

[d]Collective category contains AF, DF/Agsp, DF/Caru, GF/Clun/Clun, DF/Spbe habitat types.

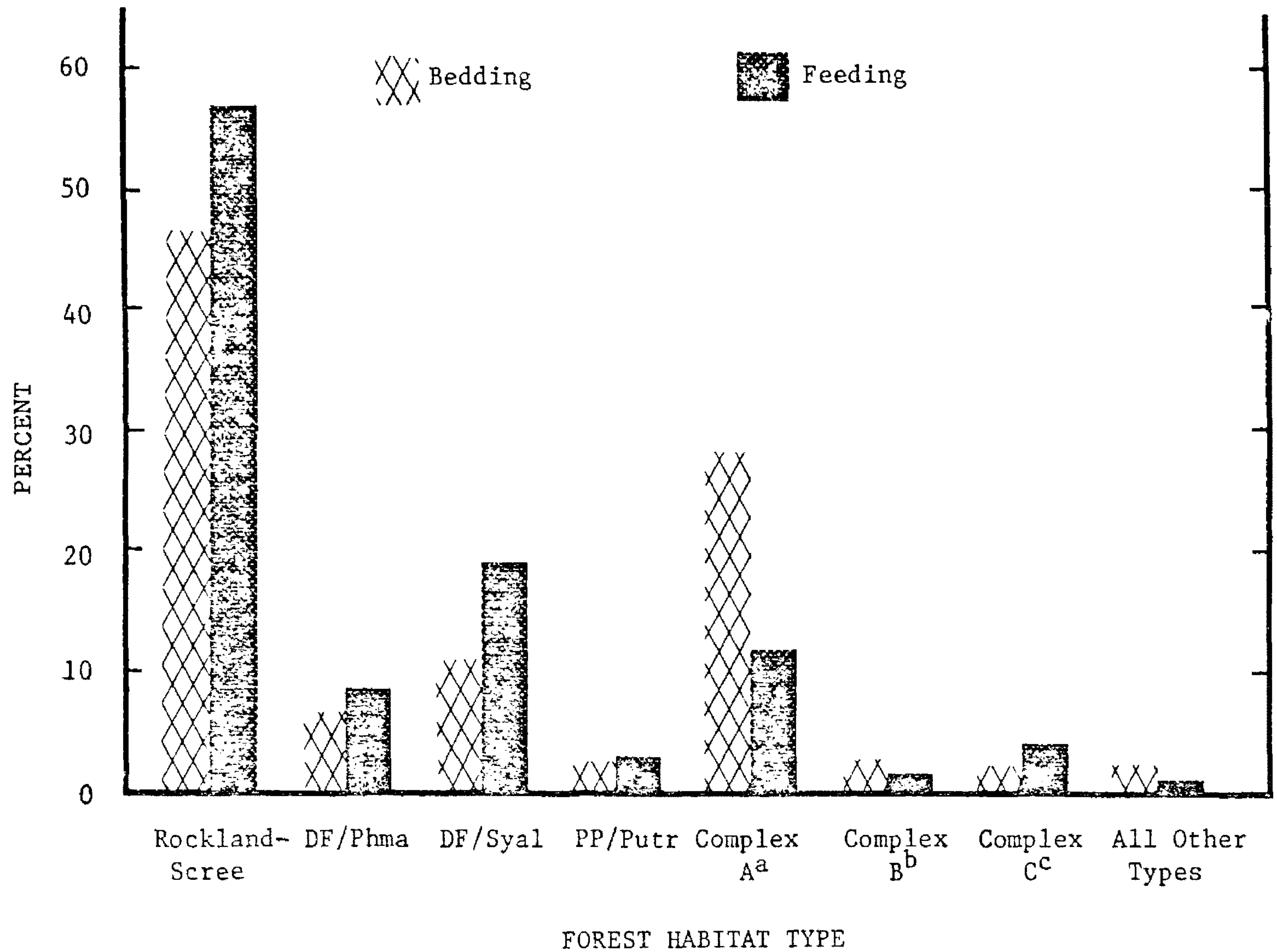

Fig. 16. Percentages of bighorn sheep group bedding and feeding sites on various habitat types.

[a]DF/Agsp-Rockland-Scree
[b]DF/Agsp-DF/Phma-Rockland-Scree
[c]DF/Phma-DF/Fesc-Rockland-Scree

Table 16. Comparisons of habitat use by ewe-juvenile, young ram, and adult ram bighorn sheep groups.

Habitat factor	Group Type: Ewe-juvenile	Young ram	Adult ram
Mean distance to nearest conifer (feet)	57.6	46.3	43.0
Mean elevation	3333	3073	4231
Mean distance to 15-foot-minimum cliff (feet/meters)	132/40.2	101/30.8	50/15.2
Percentages of observations at various elevations			
2800 feet	25.9	37.5	7.4
2810-3200 feet	20.9	37.5	3.7
3210-3600 feet	25.3	12.5	7.4
3610-4000 feet	17.1	0	22.2
4010-4400 feet	7.6	12.5	14.8
4410-4800 feet	3.2	0	25.9
4800 feet	0	0	18.5
Percentages of observations at various distances from steep terrain (80% slope, 4 ac (1.6 ha) minimum size)			
.1 miles	57.6	75.0	40.7
.11-.20 miles	26.6	12.5	29.6
.21-.30 miles	7.0	0	7.4
.31-.40 miles	7.6	0	11.1
.41 miles	1.3	12.5	11.1
Percentages of observations on various topographic positions			
Drainage bottom	.6	12.5	0
Lower slope	26.6	12.5	0
Middle slope	34.8	25.0	14.8
Upper slope	10.8	0	25.9
Ridge	9.5	12.5	33.3
Cliff	17.7	37.5	25.9
Percentages of observations on various degrees of slope steepness			
0-10 percent	2	0	0
10-35 percent	2	14	9
35-60 percent	45	57	63
60-80 percent	37	29	14
80 percent	14	0	14
Percentages of observations on various aspects			
Northwest, North, and Northeast	.6	0	0
East	1.3	0	3.7
Southeast	4.4	0	22.2
South	53.2	50.0	33.3
Southwest	35.4	25.0	22.2
West	5.1	25.0	18.5
Percentages of observations on various plant cover types			
Rockland	15.2	0	7.4
Shrubland	44.9	37.5	51.8
Open Forest	39.2	62.5	37.0
Closed Forest	.6	0	.6
Percentages of observations on various forest habitat types			
Rockland and Scree	54	63	15
DF/Agsp-Rockland and Scree	11	12	65
DF/Syal/Syal	18	25	4
DF/Phma	8	0	12
DF/Spbe	1	0	4
DF/Agsp-DF/Phma-Rockland and Scree	3	0	0
DF/Phma-DF/Feac-Rockland and Scree	3	0	0
PP/Putr	2	0	0
Total number of group observations	158	8	27

Barometric Pressure and Temperature

The temperature records from the thermographs at 2,700 feet (823 m) and 4,300 feet (1,311 m) are illustrated in Figure 17. The barometric pressure record for the corresponding period is included in the figure.

Habitat Use Related to Meteorological Conditions

The only non-trivial Pearson correlation coefficients for meteorological variables versus possible dependent variables at a significance level of 0.01 were barometric pressure versus elevation ($r = -.206$, $n = 195$) and barometric pressure versus distance to the nearest 15-foot-minimum (4.6 m) cliff ($r = 0.167$, $n = 195$). Significant (0.05) variation in mean elevation and mean distance to nearest 15-foot-minimum cliff during periods of low, medium, and high barometric pressures were revealed by analysis of variance (Table 17). Mean group size exhibited significant (0.05) variation during periods of decreasing, relatively stable, and increasing barometric pressure (Table 18).

Mean elevation of 44 group observations during temperature inversion conditions was 3,640 feet (1,109 m) while mean elevation of 153 observations during non-inversion conditions was 3,402 feet (1,037 m). A t-test established that this was a significant (0.05) difference.

Due to mild winter conditions, snow cover was entirely absent below 5,100 feet (1,554 m) elevation during most of the winter. Above this elevation, adult ram groups were observed to avoid fresh snow in excess of approximately 18 inches (46 cm). When melting and refreezing

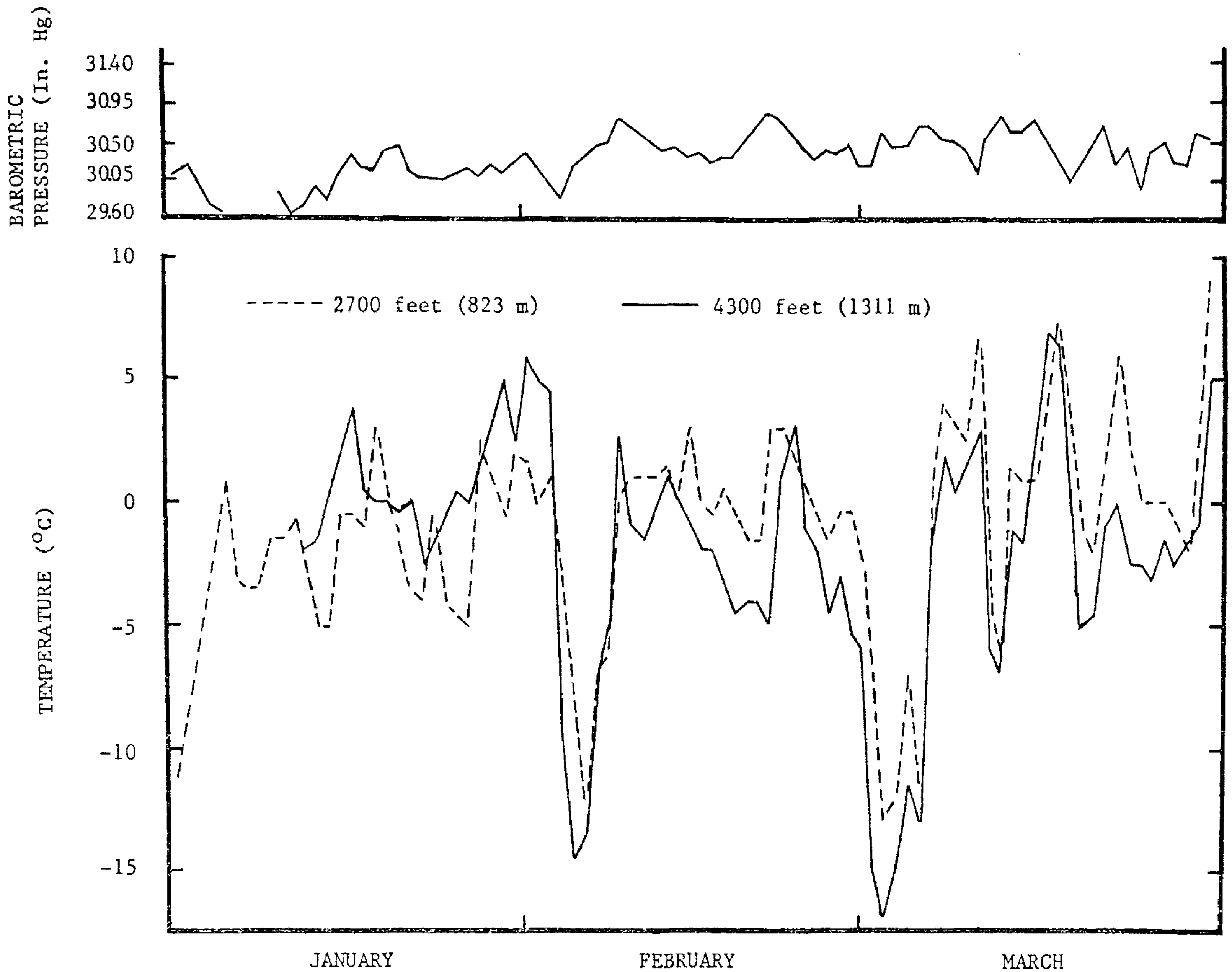

Fig. 17. Barometric pressures (top) and temperatures at two elevations (bottom) during the study period.

Table 17. Mean elevation and mean distance to the nearest 15-foot-minimum (4.6 m) cliff of bighorn sheep groups during low, medium, and high barometric pressures.

Barometric Pressure	Mean elevation (feet/m)	Mean distance nearest cliff (feet/m)	Number of obser-vations
Low ($\leq$ 30.38 in. Hg)	3621/1104	87/27	62
Medium (30.39-30.59 in. Hg)	3422/1043	116/35	68
High ($\geq$ 30.60 in. Hg)	3334/1016	158/48	67

Table 18. Comparison of bighorn sheep mean group size during periods of decreasing, relatively stable, and increasing barometric pressure.

Barometric Pressure Trend (previous 4 hours)	Mean group size	Number of obser-vations
Decreasing ($<$ -.005 in. Hg gain/hr)	4.64	61
Relatively stable (-.005 to .005 in. Hg gain/hr)	6.26	73
Increasing ($>$ .005 in. Hg gain/hr)	5.73	63

created crust characteristics that resulted in sheep track depths of 2 inches (5 cm) or less, some use of snow covered areas was noted.

Bedding Site Characterization

During the study, 189 bedding sites were categorized as night beds or day beds. Table 19 provides a comparison of various habitat characteristics associated with day and night bedding sites. In general, night bedding sites were closer to cliffs and in areas of greater conifer density than day bedding sites were.

Fecal pH

The difference in mean fecal pH values for bighorn sheep and mule deer shown in Table 20 was significant ($p = 0.05$) by a t-test. However, the large amount of overlap in pH values prevented the development of fecal pellet differentiation guidelines based on pH.

Fecal Group Counts Related to Site Factors

For all statistical analyses of fecal pellet plot data, the three different sampling areas (lower slope, upper slope, and ridge) were treated separately. Fecal group frequency distributions were compared with a theoretical Poisson distribution (Loveless 1967). A Poisson distribution requires that the probability of containing a fecal group is small and constant for all plots. The results of chi-square tests of goodness of fit are shown in Table 21. This evidence suggests random distribution of fecal groups on lower slopes and ridges. Mean fecal groups per plot were 2.45, 1.0, and 0.88 for the ridge, upper slope, and lower slope samples, respectively.

Table 19. Comparison of habitat characteristics associated with day bed sites and night bed sites.

Characteristic	Day Bed Sites			Night Bed Sites		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Distance to cliff (feet)	1	200	12.5	3	300	73
Conifer canopy cover (percent)	0	86	21	6	95	63
Conifer density (Stems/acre)	.4	76	17	7	155	22
Conifer basal area (ft^2/acre)	0	93.3	20.9	8.3	127.2	26.6
Average distance to closest conifer (feet)	8	155	63	1	26	9
Sample Size		121			68	

Table 20. Comparison of winter fecal pH values of bighorn sheep and mule deer.

Species	Mean	S.D.	95% C.L.	Range
Bighorn sheep	6.92	.15	±.04	6.58-7.30
Mule deer	6.85	.16	±.05	6.44-7.25

Table 21. Observed fecal group frequency distributions compared with theoretical Poisson probabilities.

Sampling area[a]	No. of pellet groups/ plot	Observed frequency	Poisson expected frequency		X^2
Lower slope	0[b]	48	45.69		.117
	1	29	31.00		.129
	2	9	10.51		.217
	3-4	4	2.80		.514
				Total =	.977[c]
Upper slope	0	9	15.45		2.69
	1	26	15.45		7.20
	2-4	7	11.10		1.51
				Total =	11.40[d]
Ridge	0	13	6.54		6.38
	1	15	16.01		.06
	2	15	19.62		1.09
	3	12	16.02		1.01
	4	11	9.80		.15
	5-11	9	8.01		.12
				Total =	8.81[e]

[a]Sample size is 90 on lower slope, 42 on upper slope, and 76 on ridge sampling areas.

[b]The mean number of pellet groups per plot was 0.678 for the lower slope, 1.00 for the upper slope, and 2.45 for the ridge sampling areas.

[c]Pellet groups were randomly distributed within this sampling area ($p = 0.05$).

[d]Pellet groups were not randomly distributed within this sampling area ($p = 0.05$).

[e]Pellet groups were randomly distributed within this sampling area ($p = 0.05$).

Pearson correlation coefficients (Mendenhall 1971) were calculated for fecal group counts per plot versus elevation, distance to the nearest 15-foot-minimum cliff (4.6 m), distance to the nearest conifer, conifer canopy coverage, and conifer density (stems/acre). Correlation coefficients at significance levels $\leq$ 0.05 are reported in Table 22. Distance to the nearest cliff was negatively correlated (fewer pellet groups at greater distances from cliffs) with pellet group counts on all three sampling areas. Distance to the nearest conifer was negatively correlated with fecal group counts on lower slopes. In the ridge sample, elevation was positively correlated with fecal group counts.

Kendall rank order correlation coefficients (Nie et al. 1975) were calculated for fecal group counts per plot versus total graminoid cover, total shrub cover, and canopy coverage classes for all individual shrub species. Correlation coefficients at significance levels $\leq$ 0.05 are reported in Table 22. The highest correlation obtained (0.56) was for total graminoid cover on lower slopes.

Food Habits

Microhistological analysis of fecal material found bluebunch wheatgrass to have the highest percent relative density of any plant species (Table 23). Graminoids constituted 38.01 percent of the winter fecal material, trees and shrubs constituted 51.38 percent, and forbs 10.60 percent. Mountain maple and serviceberry occurred most often in the browse class and yarrow was the most abundant forb species in winter fecal pellets.

Table 22. Relationships of fecal group locations[a] to various site factors.

Sampling area	Site characteristic	Pearson correlation coefficient	Kendall correlation coefficient
Lower slope	Distance to nearest cliff	-.18*	
	Distance to nearest conifer	-.22*	
	Total graminoid cover		.56***
	Bitterbrush canopy cover		.25*
	Rabbitbrush canopy cover		.19**
	Total shrub cover		.21*
Upper slope	Distance to nearest cliff	-.18*	
	Total graminoid cover		.25*
	Mockorange canopy cover		-.36**
	Evergreen ceonothus canopy cover		.32*
Ridge	Distance to the nearest cliff	-.39***	
	Elevation	.27**	
	Serviceberry canopy cover		-.20*
	Rabbitbrush canopy cover		.19*
	Evergreen ceonothus canopy cover		.21*

[a]The number of plots included 90 on the lower slope, 42 on the upper slope, and 76 on the ridge sampling areas.

*P 0.05

**P 0.01

***P 0.001

Table 23. Percent relative densities of plant species in bighorn sheep fecal pellets deposited during winter 1975-76.

	Mean	Range	Freq. %
Grasses and grasslike plants			
Agropyron spicatum	29.37	12.43-49.33	100
Elymus spp.	3.10	0 - 6.95	80
Festuca spp.	1.84	0 - 5.66	50
Koleria cristata	.11	0 - 2.28	5
Stipa spp.	1.78	0 - 5.62	55
Carex spp.	1.81	0 - 6.18	60
Total	38.01		
Forbs			
Achillea millefolium	4.06	0 -10.82	90
Artemesia frigida	.22	0 - 2.49	10
Castilleja sp.	2.82	0 -10.32	70
Draba sp.	.34	0 - 4.51	10
Penstemon spp.	.15	0 - 3.01	5
Townsendia sp.	1.39	0 - 4.77	40
Unknown compositae	.28	0 - 5.66	5
Unknown forb	1.34	0 - 5.25	50
Total forbs	10.60		
Trees and shrubs			
Acer glabrum	11.46	2.28-16.28	100
Amelanchier alnifolia	11.02	4.77-17.97	100
Mahonia repens	1.44	0 - 5.30	45
Ceanothus spp.	6.32	0 -15.82	95
Chrysothamnus nauseosus	1.93	0 - 5.87	65
Juniperus spp.	1.83	0 - 6.14	65
Pinus ponderosa	.64	0 - 6.97	15
Prunus virginiana	2.73	0 -13.04	70
Pseudotsuga menziesii	8.21	3.41-13.83	100
Purshia tridentata	5.52	0 -13.85	85
Ribes spp.	.28	0 - 2.2	15
Total trees and shrubs	51.38		

Forage Utilization

Estimated average forage utilization for five plant species on the winter range is shown in Table 24. Mountain maple had the highest utilization of the browse species. The linear regression equation utilized to estimate the percent utilization by weight of bluebunch wheatgrass was: log (% weight removed) = 0.027 (% height removed) - 0.44529. The r^2 value for this relationship was 0.9256 for percent height removed values of 10-90 percent. Forage utilization was greater above 3,800 feet (1,158 m) for all five plant species.

Competition

The only other wild ungulates observed on the winter range were five groups of mule deer, totalling 19 animals. They were observed on shrubland-grassland cover types at a mean elevation of 4,460 feet (1,359 m). The remains of a 2.5 year old white-tailed deer, apparently killed by a mountain lion (*Felis concolor*), were discovered on 7 February 1976. Bone marrow condition indicated no evidence of stress.

Table 24. Estimated average utilization for five forage species on the winter range.

		Shrubs		Grass
Elevation	Species	% twigs browsed	% length removed	% weight removed
Less than 3800 feet (1158 m)	Amelanchier alnifolia	69	31	-
	Acer glabrum	78	51	-
	Purshia tridentata	56	-	-
	Prunus virginiana	72	-	-
	Agropyron spicatum	-	-	30
More than 3800 feet (1158 m)	Amelanchier alnifolia	88	-	-
	Acer glabrum	96	-	-
	Purshia tridentata	85	-	-
	Prunus virginiana	94	-	-
	Agropyron spicatum	-	-	55

CHAPTER V

DISCUSSION

Trapping

Bighorn sheep readily became habituated to the salt-baited portable corral trap during summer. In late July and early August, as many as 25 sheep were observed in the open trap at one time. Major disadvantages of the corral trap were the necessity for two or more people to handle the collaring operations and the injury hazard to lambs (1-4 months of age) before they could be removed to a holding pen. The hand-operated triggering device, which consisted of a rope holding the gates open and tied to a tree, operated satisfactorally with no injury to the sheep.

Large corral type traps have been used successfully for capturing bighorn sheep by various researchers (Hunter et al. 1946, Putman 1950, Aldous et al. 1958). Erickson (1970) captured 68 Dall sheep (*Ovis dalli*) at a natural mineral lick in 8 days utilizing a drop net. Apparently many wild sheep populations are susceptible to relatively efficient trapping techniques designed to capture many individuals with each setting. Although the use of a corral trap baited with salt was successful in the Thompson Falls area, it is recommended that winter trapping be attempted first. The vigorous escape attempts of yearling and adult bighorns could result in the injury or death of lambs only a few months old.

Group Size and Age-Sex Composition

The mean group size for all observations on the winter range was 5.6 (Table 4). Adult ram groups averaged 7.0 and ewe-juvenile groups averaged 5.4. Oldemeyer (1966) reported a mean winter group size of 8.7 in Yellowstone National Park. Geist (1971) reported wintering bighorns averaging 5.2 and 9.5 for male and female groups, respectively. Blood (1963) reported that the mean winter group size of ewes was greater than that of rams. The comparatively low mean winter group size on the Thompson Falls study area may reflect the diverse nature of the habitat and/or the mildness of the winter. Habitat characteristics vary in repeating patterns on the study area. Selection behavior would not be expected to result in large concentrations of animals unless snow conditions restricted movements.

The age-sex composition data (Table 5) agree with Brown's (1974) report that productivity was as great or greater than most other bighorn populations reported (Buechner 1960:80). The yearling:ewe ratio of 42:100 indicates low overwinter lamb mortality.

The male:female ratio of 68:100 (Table 5) is essentially identical to the 71:100 ratio Brown (1974) considered his best estimate. Oldemeyer (1966) reported a 78:100 male:female ratio during winter in Yellowstone National Park. Smith (1954) reported a 74:100 sex ratio in Idaho. In contrast, Woodgerd (1964) reported males to outnumber females on Wildhorse Island, Montana. Differential mortality and/or difficulty in observing one sex group could account for unequal sex ratios. Cowan (1950), Smith (1954), Sugden (1961), and Moser (1962) reported sex ratio biases due to the occupation of separate ranges by rams and ewes. The occupation of higher elevations by ram groups during winter (Table 16) on the Thompson Falls winter range probably biased male:female ratios in favor of females.

Movements and Home Range

Mean standard diameters during winter were 2.63 miles (4.23 km) and 1.89 miles (3.04 km) for adult females and adult males, respectively (Table 6). Mean minimum home range size was less for adult males than adult females (Table 7). Brown reported winter standard diameters of 3.88 miles (6.2 km) and 2.20 miles (3.5 km) for lamb and yearling males and lamb, yearling, and adult females, respectively. Erickson (1972) reported standard diameters of 0.92 mile (1.5 km) for males and 1.42 miles (2.3 km) for females during a severe winter. It is apparent from the range of standard diameters and minimum home ranges observed in this study (Tables 6 and 7) that individual differences existed within each sex group. A combination of winter severity and strength of individual home range fidelity may determine the extent of winter movements. Adult males may tend to restrict their movements more during winter than adult females do.

Availability Sample of the Study Area

As pointed out by Marcum (1975), there is an increased awareness of the need to relate the use of habitat categories by a given animal species to the availability of those factors (Nicholls and Warner 1972, Neu et al. 1974, Hirst 1975, and Peek et al. 1976). This requires that the proportion of each habitat category of interest be determined. When working with complex patterns of availability (i.e., plant community mosaics and areas a certain distance from cliffs), the mapping techniques often utilized would be extremely time consuming and difficult. The random point technique of sampling availability provided a reasonably accurate (Table 8) and time-efficient alternative.

Habitat Selection and Use

The failure of wintering bighorn sheep to utilize the various habitat categories tested in proportion to their availability is similar to the findings of Shannon et al. (1975). They reported high correlations between some habitat variables and numbers of bighorn sheep observed on a British Columbia winter range. This suggests that bighorn sheep are selective in their use of potential winter range.

Elevation. Bighorn sheep avoided portions of the winter range above 4,800 feet (1,463 m) elevation (Table 9). They exhibited no apparent preference or avoidance for other elevational categories. The only permanent snow cover on southerly slopes within the study area occurred above 5,100 feet (1,554 m) elevation. Shannon et al. (1975) and Stelfox (1975) reported a significant negative correlation between snow depth and numbers of bighorn sheep observed. Oldemeyer (1971) reported bighorn distribution to be affected by snow depth. Honess and Frost (1942), Smith (1954), Geist (1971), and Brown (1974) reported that wintering bighorn sheep select snow free sites for feeding. Honess and Frost (1942), Smith (1954), McGann (1956), Sugden (1961), Moser (1962), Blood (1963), and McCullough and Schneegas (1966) reported that bighorn sheep leave summer range in response to storms and snowfall. The avoidance of snow cover and random use of snow free portions of the study area would result in the observed pattern of elevational distribution of bighorn sheep.

Topographic position. Bighorn sheep on the winter range avoided drainage bottoms and upper slopes while exhibiting a preference for cliffs (Table 10). Oldemeyer et al. (1971) reported that 75 percent of the bighorn use during winter was on steep terrain and ridgetops, with 14 percent of sightings occuring on rocky outcrops. Brown (1974) reported that 50 percent of his bighorn observations throughout the year occurred on broken ridges, 43 percent on talus, and 7 percent on rock outcrops. A close association between wild sheep and rugged terrain has been reported by Couey (1950), Smith (1954), Flook (1962), and Schallenberger (1965). McCann (1956) stated "the ecological niche of the mountain sheep consists of temperate to subarctic conditions which provide relatively continuous cliffy or broken topography." A preference for rough terrain would account for the avoidance of comparatively smooth drainage bottoms and preference for cliffs observed in this study. The avoidance of upper slopes is more difficult to explain. The most extensive cliff areas on the winter range are above upper slopes. A lack of available forage due to the absence of stable islands of vegetation in the loose debris at the base of cliffs may account for the light use of upper slopes.

Slope steepness. Wintering bighorn sheep avoided areas having a slope steepness of 10-35 percent and preferred areas with a slope steepness greater than 80 percent (Table 11). Shannon et al. (1975) reported that bighorn sheep moved onto steep slopes in late winter. They felt that use of slopes was related to associated abiotic or biotic features rather than slope per se. The use pattern on slopes of various degrees of steepness undoubtedly reflects, at least in part, the previously discussed affinity of bighorn sheep for rough topography. The absence of an apparent avoidance behavior toward areas with a 0-10 percent slope may be a result of random variation in the data. Only 1.6 percent of the study area was classified in the 0-10 percent slope category.

Aspect. Bighorn sheep on the winter range avoided east and southeast aspects and preferred south aspects (Table 12). Shannon et al. (1975) reported a late winter bighorn sheep distribution favoring southwest exposures. Oldemeyer (1966) reported that percent use on south, southeast, southwest, west, east, and north exposures was 27, 0, 20, 29, 2, and 22, respectively. Constan (1967) reported bighorn winter utilization of south, southeast, and southwest aspects as 18, 22, and 56 percent, respectively. McCann (1956) determined that east and south facing slopes were used most heavily by wintering bighorn sheep in the Gros Ventre Range of Wyoming. Flook (1962) stated that most bighorn winter ranges in Banff and Jasper National Parks, Alberta have a southern exposure. He attributed this to the rapid dissipation of snow by direct sunlight on those aspects.

Without corresponding availability data, aspect utilization information is difficult to interpret. Since southern slopes in the northern latitudes face the direction of the winter sun, they absorb more radiant energy than other aspects (Moen 1973). A preference for these southerly aspects by wintering ungulates is undoubtedly related to this phenomenon. The absence of snow cover on most of the study area during winter suggests that the heavy use of south slopes, in this instance, was a response to microenvironmental, physical, or biotic characteristics of south slopes rather than snow depth. The utilization patterns reported by other investigators probably reflect local winter range characteristics and varying degrees of winter severity.

<u>Distance to steep terrain</u>. Areas more than 0.2 miles (322 m) from steep terrain (defined as areas greater than 4 acres (1.6 ha) with a slope steepness greater than 80 percent) were avoided by wintering bighorn sheep (Table 13). Areas within 0.2 miles (322 m) were preferred. Shannon et al. (1975) reported a significant negative correlation between numbers of bighorn sheep and distance from "escape terrain" during winter, spring, and summer. Oldemeyer et al. (1971) reported that 86 percent of winter observations of bighorn sheep were less than 100 yards (91 m) from "escape habitat". The results from the present

study are quite striking in that there were no 0.1 mile (161 m) categories that were utilized in approximate proportion to their availability (Table 13). There was a preference for lands 0.1-0.2 miles (161-322 m) from steep terrain and an avoidance of lands only 0.1 mile (161 m) farther from steep terrain. Bighorn sheep apparently have a very strong innate preference for lands in close proximity to steep terrain and will normally limit their activities to those areas.

Plant cover types. Shrubland-grassland and open forest plant cover types were preferred by wintering bighorns and closed forest was avoided (Table 14). Other plant cover types were used approximately in proportion to their availability. Smith (1954) determined in an Idaho study that percent winter use on open grass cover types was greater than percent availability and percent use on browse cover types was less than percent availability in Idaho. He reported that open timber and cliff areas were used approximately in proportion to their availability. Oldemeyer et al. (1971) reported percentages of winter bighorn use on forest, grass, and shrub vegetative types were 13, 78, and 9, respectively. Constan (1972) found winter use percentages of 2, 20, 9, and 69 on lodgepole pine, Douglas-fir, sagebrush, and bunchgrass vegetation types, respectively. The preference for shrubland-grassland and open forest on my study area may reflect the absence of large grassland areas. Bluebunch wheatgrass is locally abundant and palatable shrubs are common on shrubland and open forest cover types. A preference for cover types containing the most forage would account for the observed utilization pattern.

The higher percentage of bedding sites than feeding sites on rocklands reflects both lack of forage plants on rocklands and the tendency for bighorns to bed in rocks on sunny winter days. The open timber cover type received a higher percentage of feeding use than bedding use. This may reflect a preference for day bed sites without nearby conifers that would obstruct the view of the surrounding terrain. This differential use of habitat for day time bedding and feeding activities is in contrast to Smith's (1954) report that bighorns selected day beds wherever they happened to be feeding.

Forest habitat types. Wintering bighorn sheep preferred rockland and scree and avoided the DF/Phma habitat type (Table 15). Other major habitat types were used in approximate proportion to their availability. The apparent selective behavior of bighorn sheep in regard to forest habitat types (potential climax communities) is most readily explained in terms of the present physical and biotic characteristics of the land. The rockland and scree habitat type classification is currently vegetated by the rockland and shrubland-grassland plant cover types. A preference by bighorn sheep for areas with cliffs, steep slopes, and available forage probably accounted for the high use of rockland and scree. A significant proportion of the DF/Phma habitat type on the study area occurred at high elevations on east and southeast aspects (Fig. 4). In addition, most of the DF/Phma habitat type was occupied by a closed timber cover type. The association of these habitat characteristics with the DF/Phma habitat type probably account for the low level of observed use.

Comparison of Habitat Use by Group Type

Adult ram groups were observed at significantly ($p = .001$) higher elevations than ewe-juvenile or young ram groups (Table 16). Adult ram groups were never observed in close proximity to ewe-juvenile groups after 20 January 1976. Observations of separation of bighorn sheep into sex groups have been reported by Couey (1950), Smith (1954), Moser (1962), Blood (1963), and Geist (1971). Grubb and Jewell (1966) observed ewe and ram group separation in feral Soay sheep on Hirta Island, Great Britain. In discussing bighorn sheep and some other northern ungulates that have access to mountains, Cowan (1974) stated they "evince acrophilia, which leads them to remain at the highest possible altitude on the winter range slopes. This behavior is most strongly evinced by the males and in them is one feature leading to a higher mortality rate." Such behavior would explain the sex-group separation observed on the Thompson Falls winter range.

Percentages of adult ram and ewe-juvenile group observations at distances greater than 0.3 miles (483 m) from steep terrain were 22.2 and 8.9, respectively (Table 16). In contrast, mean distance to the nearest 15-foot-minimum (4.6 m) cliff was 50 feet (15.2 m) and 132 feet (40.2 m) for adult ram and ewe-juvenile groups, respectively. These results may partially reflect the topographical nature of the study area rather than a difference in selective behavior. The upper elevational ranges contain more small rock outcrops than lower elevation areas do. Selection for higher elevations by ram groups might account for the observed difference in mean distance to the nearest 15-foot-minimum (4.6 m) cliff. Major steep terrain areas, however, appear to have been equally available to all groups during the winter (Fig. 16).

Blood (1963) reported that ewe-lamb groups selected winter habitat with more readily available escape terrain than that selected by rams. If distance to escape terrain at the moment of predator attack is directly related to the probability of an individual bighorn surviving the attack, heavy predation pressure could have been a factor in the development of an affinity for rough topography. If that was the case, females might be expected to exhibit a higher development of the trait since a greater affinity for cliffs would not only increase their individual chances of survival, but would increase the survival chances of their relatively vulnerable offspring.

The habitat use characteristics of young ram groups were nearly identical to those of ewe-juvenile groups (Fig. 16 and Table 16). Geist (1975) reported that young rams tend to increase the activity of females by courting them throughout much of the year. He stated that any harvest programs should be designed to insure adequate older rams in the population to draw young rams with them and away from the females. The limited number of observations of young ram groups during this study tend to confirm that ram bands composed solely of sub-adult ($<$ 3/4 curl) males will not occupy distinctly different winter range than ewe-juvenile groups.

Habitat Use Related to Barometric Pressure and Temperature

There was a significant ($p = 0.05$) variation in mean elevation and mean distance to the nearest 15-foot-minimum (4.6 m) cliff during periods of low, medium, and high barometric pressure (Table 17). Bighorns were observed at higher elevations and closer to cliffs during periods of low barometric pressure. Mean elevation during temperature inversion and non-inversion conditions was 3,640 feet (1,109 m) and 3,402 feet (1,036 m), respectively. This was a significant ($p = .05$) difference. Geist (1971) stated that mountain sheep "appear to prefer the warmest elevations of the mountains, keeping in the warm air above the thermocline."

An inspection of Fig. 17 reveals that low temperature extremes during the study period were accompanied by medium to high barometric pressures. During these low temperature extremes, it was warmer at 2,700 feet (823 m) elevation than at 4,300 feet (1,311 m). Temperature inversion conditions during January and early February, indicated by higher temperatures at higher elevations, were accompanied by low to medium barometric pressures. A preference by wintering bighorn sheep for the warmest temperatures available to them would account for high utilization of lower elevations during high barometric pressure periods. This type of behavior would also account for the increased use of higher elevations during temperature inversions.

The low average distance to the nearest 15-foot-minimum (4.6 m) cliff under low barometric pressure conditions is probably a reflection of the physical characteristics of the winter range. Lower elevational areas contain fewer small rock outcrops than higher elevations do. An upward altitudinal movement toward higher temperatures during inversion conditions (which tended to be periods of low to medium barometric pressure) would result in bighorn sheep groups being observed closer to 15-foot-minimum (4.6 m) cliffs.

Mean group size exhibited significant ($p = 0.05$) variations during periods of decreasing, relatively stable, and increasing barometric pressures (Table 18). The highest mean group size occurred during conditions of relatively stable barometric pressure and the lowest during decreasing pressure conditions. Stelfox (1975) reported a significant ($p = 0.001$) positive correlation ($r = 0.256$) between barometric pressure and numbers of bighorn observed on open winter ranges. This was interpreted as reflecting an abandonment of exposed winter grasslands with the onset of lower barometric pressures preceding winter storms. The reduction in mean group size during periods of decreasing barometric pressure observed in this study may reflect a tendency by bighorn sheep to seek shelter in anticipation of a storm. Oldemeyer (1966) reported that bighorn sheep in Yellowstone National Park often utilized small patches of conifers and deep ravines as shelter. Such behavior during decreasing barometric pressures would make bighorns less observable and might result in smaller observed group sizes.

Bedding Site Characterization

The mildness of the 1975-76 winter in the Thompson Falls area resulted in poor tracking conditions due to lack of snow cover. As a result, only 189 bedding sites of known use periods could be located (Table 19). The small sample size precludes definite conclusions about possible differences in characteristics of day and night bedding sites. The data is suggestive, however, of a positive association between night bedding sites and conifer cover. Beall (1974) reported that elk selected night bedding sites with greater conifer density as temperature decreased. Moen (1968) pointed out the energy conservation advantages of bedding near conifers. Geist (1971) stated "Wintering mountain sheep reduce waste of energy by avoiding excessive heat loss and excessive energy expenditures in foraging and social life. . . ." The mean distance to the closest conifer and mean canopy coverage characteristics of night bedding sites suggest that microclimatic conditions related to conifer cover may influence selection of night bedding sites by bighorn sheep. The presence of conifers on the winter range is probably not essential to winter survival since Spencer (1943), Moser (1962), and Flook (1972) reported bighorn sheep wintering above treeline. Further research into energy expenditure by wintering bighorn sheep is necessary before the potential importance of conifer cover on winter range can be evaluated.

Fecal pH

There was a significant ($p = 0.05$) difference in mean fecal pH values for bighorn sheep (6.92) and mule deer (6.85) (Table 20). However, the technique failed to provide useful species differentiation criteria due to the large amount of overlap in fecal pH values. In contrast, Howard (1967), Nagy and Gilbert (1968), Howard and DeLorenzo (1974), and Krausman et al. (1974) reported fecal pH to be a useful method for differentiating ruminant fecal pellets. The failure of the fecal pH method to adequately differentiate between mule deer and bighorn pellets on the Thompson Falls winter range underscores the warning of Howard and DeLorenzo (1974): "We believe each area and species of interest should be studied carefully before applying the technique in large management situations."

Food habits

Microhistological analysis of fecal material indicated that the winter diet consisted of approximately 38 percent grasses and sedges, 51 percent browse, and 11 percent forbs (Table 24). Bluebunch wheatgrass had the highest percent relative density in the winter fecal material, followed by mountain maple, servicebarry, Douglas-fir, Ceonothus spp., bitterbrush, and yarrow in decreasing order. Food habits studies from other bighorn sheep populations indicate that the percentages of grasses and sedges, browse, and forbs in the winter diet vary widely. Schallenberger (1965) reported that the bighorn winter diets in the Sun River, Montana, area consisted of 36 percent grass, 43 percent browse, and 21 percent forbs. Blood (1963) reported that British Columbia winter bighorn diets were comprised of 72 percent grasses, 24 percent browse, and 4 percent forbs, with bluebunch wheatgrass the most important forage species. Oldemeyer et al. (1971) reported bighorn winter utilization percentages of 61.4, 21.5, and 17.2 for grasses and grasslike plants, shrubs, and forbs, respectively. Bluebunch wheatgrass was the main forage species.

Bluebunch wheatgrass, mountain maple, and serviceberry accounted for over 51 percent of the plant fragments in winter fecal material from the Thompson Falls study area. Management for the perpetuation of these species on the winter range is recommended. The large percentage of browse in the winter diet probably reflects the relative scarcity of grasslands on the winter range. The high productivity of the population indicates that a browse-dominated winter diet is adequate. Demarchi (1968) reported yarrow to be high in crude fat and crude protein in March on British Columbia bighorn sheep winter ranges. The preference for yarrow over other forbs by the Thomspson Falls bighorn sheep is probably related to forage quality. Douglas-fir accounted for over 8 percent of plant fragments in winter feces. Simmons (1961), Moser (1962), and Capp (1967) reported conifers in winter bighorn diets. The relatively large amount of Douglas-fir in the diet of a healthy population under no apparent nutritional stress may indicate that this particular conifer fulfills some nutritional requirement. It is also possible that relatively high utilization of more preferred forage species has resulted in the incorporation of less preferred species into the diet.

Forage Utilization

Utilization, as measured by percentage of twigs browsed on lower elevation areas, was 69, 78, 56, and 72 percent for serviceberry, mountain maple, bitterbrush, and chokecherry, respectively (Table 25). Bluebunch wheatgrass utilization at lower elevations was 30 percent by weight. Utilization levels increased at higher elevations with at least 85 percent of the twigs browsed on all shrub species measured. Bluebunch wheatgrass utilization was 55 percent by weight at higher elevations. Oldemeyer et al. (1971) reported that utilization of bluebunch wheatgrass in Yellowstone National Park exceeded 70 percent on two winter ranges. Stelfox (1975) reported 58 percent grass utilization on three heavily used ranges he considered overgrazed.

Increased forage utilization at higher elevations on the Thompson Falls study area was probably due to the use of those areas year-long by bighorn sheep. The upper elevation sampling areas between 3,800 and 5,000 feet (1,158 and 1,524 m) were used heavily by rams during the 1975-1975 winter. Casual observations established that these same areas were used by ewes and juveniles during late spring and summer when bighorn sheep were very rarely seen at lower elevations.

The utilization transects were located in areas known to have received moderate to heavy bighorn use and thus represent the heaviest degrees of utilization on the study area. In addition, the degree of forage utilization on a particular site within the winter range may vary considerably from year to year.

During a severe winter, bighorn sheep would be expected to move to shallower snow depths at lower elevations. Winter forage utilization at lower elevations was not excessive during the study period, but the quantity of available forage might not be adequate during a severe winter. The ramifications of heavy utilization of preferred forage species at higher elevations are unclear. Stelfox (1975) reported that high forage utilization levels were correlated with low forage production, high lungworm counts, high winter weight loss, and low yearling:ewe ratios. A more intensive investigation of forage utilization and its relation to carrying capacity on the Thompson Falls bighorn sheep range is recommended.

Competition

Five groups of mule deer were the only wild ungulates observed on the winter range in addition to bighorn sheep. The Thompson Falls bighorn sheep are not seriously affected by competition with other native ungulates.

Fecal Group Counts Related to Site Factors

Observations of wintering ungulates with fecal pellets similar to those of bighorn sheep totalled 19 mule deer. Total bighorn observations during the same period were 1,103. It was concluded that there was no significant error in winter fecal group counts due to the presence of fecal pellets not deposited by bighorn sheep. Mean fecal groups per plot were 2.45, 1.00, and 0.68 for the ridge, upper slope, and lower slope samples, respectively.

The high number of fecal groups on ridges was apparently the result of frequent use of these areas as bedding sites. The highest concentrations of fecal groups on the study area occurred in heavily used bedding areas. The positive correlation ($r = 0.27$) between fecal group counts and elevation on ridges (Table 22) reflects the heavy use of higher elevations in the sampling area by adult rams. The correlations of rabbitbrush ($r = 0.19$), serviceberry ($r = -0.20$), and evergreen ceonothus (r = 0.21) canopy coverages with fecal group counts on ridges are difficult to explain (Table 23). If fecal group counts on ridges were highest in the vicinity of major forage species in the diet (Table 24), the correlations with serviceberry and evergreen ceonothus would both be positive. This was not the case. In contrast to lower and upper slopes, fecal group counts on ridges were not positively correlated with graminoid canopy cover. Fecal group distribution on ridges evidently reflects bedding site selection more than feeding site selection.

Distance to the nearest 15-foot-minimum (4.6 m) cliff was negatively correlated with fecal group counts on all three sampling areas (Table 22). The group observation data, which established that areas in close proximity to steep terrain were preferred by wintering bighorn sheep (Table 13), indicated similar distribution of bighorns.

Distance to the nearest conifer was negatively correlated (r = 0.22) with fecal group counts on lower slopes (Table 22). Significant positive correlations existed between fecal group counts and canopy coverages of total graminoids, bitterbrush, rabbitbrush, and total shrubs (Table 23). Graminoid cover was positively correlated with canopy coverages of bitterbrush, rabbitbrush, and total shrubs. Lower slopes were occupied primarily by the rockland and open forest cover types with lesser amounts of shrubland-grassland. Sparsely vegetated rubble fields are intermingled with open Douglas-fir-ponderosa pine forests and small shrubland-grasslands containing bluebunch wheatgrass and preferred browse species. The group observation data revealed that open forest and shrubland-grassland cover types were preferred by wintering bighorn sheep (Table 14). On lower slopes, important forage species such as bluebunch wheatgrass (Table 24) were associated with conifers. A selection for areas containing preferred forage species would account for the observed pattern of fecal group distribution on lower slopes.

On upper slopes, canopy coverages of total graminoids and evergreen ceonothus were positively correlated (Table 23) and mockorange canopy coverage was negatively correlated with fecal group counts. Evergreen ceonothus canopy cover was negatively correlated ($r = -0.15$, sig. = 0.15) with mockorange canopy cover. A preference for graminoids and evergreen ceonothus as food items probably accounts in part for pellet group distribution on upper slopes.

Management Implications

The Thompson Falls bighorn sheep exhibited a great deal of selectivity in their use of available habitat during this study (Tables 9-15). This information suggests that habitat modification projects designed to improve bighorn sheep winter range in the Thompson Falls area should be concentrated on south and southwest aspects within 0.2 miles (322 m) of steep terrain ($>$ 80 percent slope). The principal management objective should be the perpetuation of the shrubland-grassland and open forest cover types. These types received 85 percent of bighorn winter use and contain far more bighorn winter forage than rockland or closed forest cover types did (Tables 2 and 24).

Other populations of bighorn sheep may not exhibit winter habitat selection patterns identical to those of the Thompson Falls population. However, the information from this study may be useful in evaluating potential bighorn sheep transplant sites, particularly if the transplant animals are taken from the Thompson Falls population. Potential winter ranges should include grassland, shrubland, or open forest cover types containing palatable forage within approximately 0.2 mile (322 m) of steep terrain. These open cover types should be located on southerly aspects at lower elevations.

The potential climax plant community on a particular land unit was not an important determinant of winter habitat selection by bighorns on the Thompson Falls winter range (Table 15). Winter distribution of sheep was related to the existing plant community (plant cover type) (Table 14), which was often quite different structurally and floristically from the potential climax community. Once the plant cover types important to an animal species are identified, the successional status of these communities becomes an important management consideration. On the Thompson Falls study area, many of the shrubland-grassland and open forest plant cover types on southerly slopes at lower elevations occur on a DF/Syal/Syal habitat type (Fig. 4). These areas have the potential to become closed forests containing little bighorn forage. Because the sites are harsh, plant succession is not progressing at a rapid rate. However, if the maintenance of a large bighorn sheep population is the primary management objective on these lands, it may be necessary to reduce the conifer canopy cover at some time in the future.

Prescribed burning is probably the most desirable method of reversing plant succession on bighorn ranges. Fire has been described as important in creating desirable conditions on mountain sheep ranges by Flook (1964), Geist (1971), and Stelfox (1971). Asherin (1973) reported an increase in available production of mountain maple and serviceberry after prescribed burning in northern Idaho. He also reported higher use by wintering elk and white-tailed deer on burned sites in comparison to control sites that were not burned. Vallentine (1971) reported that several studies indicated bluebunch wheatgrass was slightly damaged by fire. Conrad et al. (1966) determined that only 1 percent of bluebunch wheatgrass plants were dead 11 months after an eastern Oregon fire. These findings indicate that fire is an important factor on many ranges and would not be detrimental to the most important forage species on the Thompson Falls winter range.

Fecal group counts provided a remarkably accurate index to the relative distribution of bighorn sheep in relation to various habitat factors (Table 22). Nearness to cliffy areas and high total graminoid canopy cover were the habitat factors most consistently correlated with high fecal group counts. The group observation data confirmed that areas close to steep terrain and areas vegetated by the plant cover types containing the highest coverages of total graminoids were preferred by wintering bighorn sheep (Tables 13 and 14). The sampling of fecal group distribution may provide a reasonably accurate, inexpensive method of estimating relative habitat use by bighorn sheep on many winter ranges.

Determining the proper carrying capacity of the Thompson Falls bighorn sheep range is a complex problem. High forage utilization levels at middle to high elevations may indicate the initial stages of range deterioration (Table 25). However, without comparative data from previous years, the significance of this information is not clear. The population is currently highly productive with heavy body weights and low lungworm levels (Brown 1974). Rocky Mountain bighorn sheep populations that reach high population levels are typically reduced by a rapid dieoff. In discussing the bighorn sheep of the Canadian Rockies, Stelfox (1971) stated "During pristine times bighorns underwent sporadic fluctuations caused by severe winters, disease, and changes in the condition of their ranges, influenced by weather, fire, and interspecific competition." Buechner (1960) described these reductions:

> "If barriers such as restricted winter forage, deep snow, and drought do not limit levels of population, a point of high density is reached where disease causes a sudden and severe mortality. The principal disease involved is caused by lungworm. The triggering mechanism seems to be poor nutrition from temporary deterioration of forage on winter concentration areas . . . The lungworm-pneumonia complex is unquestionably the most significant disease in bighorn sheep."

Population reductions do occur that are not accompanied by a high level of lungworm infection. Berwick (1968) and Matthews (1973) reported low lungworm levels in two declining western Montana bighorn populations.

A massive dieoff may reduce the Thompson Falls population if it continues to increase at the present rate. Stabilization of the population at or below some unknown critical level would greatly reduce this probability. If a stabilized population is chosen as a management objective, more information on the carrying capacity of the Thompson Falls range would be necessary.

To adequately assess the status of the Thompson Falls bighorn sheep population in relation to carrying capacity, a long term monitoring program is necessary. The collection of yearly data on herd sex and age characteristics, lungworm loads, and forage utilization levels would provide the minimum information necessary for management decisions. I recommend that such a monitoring program be initiated.

CHAPTER VI

SUMMARY

Winter habitat selection and use by bighorn sheep were investigated near Thompson Falls in northwestern Montana. The study area was located in the southeast end of the Cabinet Range overlooking the Clark Fork River. The precipitous terrain is characterized by poorly developed soils and numerous talus cones emanating from rugged crags of exposed bedrock. Intensive observations of wintering sheep between 1 January and 30 March 1976 provided data on herd sex and age characteristics, group size, movements, home range, and habitat selection. The relatively mild winter was characterized by moderate temperatures and a lack of snow cover. Other data collecting activities provided information on existing plant communities, potential climax plant communities, fecal group distribution, fecal pH, bighorn winter food habits, and estimated average percent utilization of five major forage species.

Mean group size of 197 bighorn sheep groups observed during the winter was 5.6. The mean size of adult ram groups was higher than that of ewe-juvenile or young ram groups. Lamb:ewe and yearling:ewe ratios were 92:100 and 42:100, respectively. Mean standard diameters for adult females and adult males were 2.63 miles (4.23 km) and 1.89

miles (3.04 km), respectively. Mean minimum home range sizes were 320 acres (129.5 ha) and 271 acres (109.6 ha) for adult females and adult males, respectively.

Proportions of group observations within individual categories of elevation, topographic position, slope steepness, aspect, distance from steep terrain, plant cover type, and habitat type were compared with the proportion of occurrence of those categories within the study area. Results indicated an avoidance of elevations above 4,800 feet (1,463 m), drainage bottoms and upper slopes, areas with a slope steepness of 10-35 percent, east and southeast aspects, areas greater than 0.2 miles (322 m) from steep terrain, closed forests, and the Douglas-fir/ninebark habitat type. Preferences were shown for cliffs, areas with a slope steepness greater than 80 percent, south aspects, areas within 0.2 miles (322 m) of steep terrain, shrubland-grassland and open forest, and the rockland-scree habitat type classification. Measurements taken at a small number of bedding sites indicated that bighorn sheep night bedding sites may be associated with conifers.

Adult ram groups were observed at significantly higher elevations than ewe-juvenile or young ram groups. In general, the winter habitat selected by young ram groups was similar to that selected by ewe-juvenile groups.

Bighorns apparently sought out comparatively warmer elevations during the winter. Mean group size was lowest during periods of decreasing barometric pressure.

The winter diet of bighorns, as estimated by microhistological examination of feces, was 38 percent grasses and sedges, 51 percent browse, and 11 percent forbs. Bluebunch wheatgrass, mountain maple, serviceberry, and Douglas-fir had the highest percent relative densities in fecal material, in decreasing order. Percentages of twigs browsed on four major forage species exceeded 55 and 84 percent below and above 3,800 feet (1,158 m), respectively. Bluebunch wheatgrass utilization by weight was 30 and 55 percent at lower and higher elevations, respectively.

Measurement of fecal pH values of bighorn sheep and mule deer failed to provide a useful means of pellet group identification by species. High fecal group counts were most consistently correlated with low distances to the nearest cliff and high total graminoid canopy coverages. The relative use of habitats by bighorn sheep as estimated by fecal group counts was generally similar to that indicated by direct observations of wintering animals.

The perpetuation of shrubland-grassland and open forest cover types on the winter range by prescribed burning was recommended when canopy coverages warranted conifer removal.

A long-term monitoring program to assess the status of the Thompson Falls population in relation to carrying capacity was recommended. This program would involve the systematic collection of data on sex and age characteristics, lungworm loads, and forage utilization levels.

REFERENCES CITED

Alden, W. C. 1953. Physiography and glacial geology of western Montana and adjacent areas. U.S. Geological Survey Professional Paper 231. U.S. Government Printing Office, Washington, D.C. 200 pp.

Aldous, M. C. 1958. Trapping and tagging of bighorn sheep. Trans. Desert Bighorn Council 2:36-39.

Alt, D. D., and D. W. Hyndman. 1972. Roadside geology of the northern Rockies. Mountain Press Publishing Co., Missoula, MT. 280 pp.

Anonymous. 1973. Habitat type inventory standard and procedure for multiple use planning. USFS, Region 1, Lolo Nat. For., Missoula, MT.

________. 1976. Draft environmental statement multiple use plan - Big Hole Planning Unit. USFS, Region 1, Lolo Nat. For., Plains and Thompson Falls Ranger Dist., MT. 137 pp.

Asherin, D. A. 1973. Prescribed burning effects on nutrition, production and big game use of key northern Idaho browse species. Ph.D. Thesis, Univ. ID, Moscow. 96 pp.

Beall, R. C. 1974. Winter habitat selection and use by a western Montana elk herd. Ph.D. Thesis, Univ. MT, Missoula. 197 pp.

Berwick, S. H. 1968. Observations on the decline of the Rock Creek, Montana population of bighorn sheep. M.S. Thesis. Univ. MT, Missoula. 245 pp.

Blood, D. A. 1963. Some aspects of behavior of a bighorn herd. Canad. Field Nat. 77(2):77-94.

Bodie, W. L., and W. O. Hickey. 1976. Bighorn sheep trap design and suggested procedure. Information paper, ID Fish Game Dept., Salmon. 7 pp.

Bowden, D. C., A. E. Anderson, and D. E. Medin. 1969. Frequency distributions of mule deer fecal group counts. J. Wildl. Manage. 33(4):895-905.

Brown, G. W. 1974. Distribution and population characteristics of bighorn sheep near Thompson Falls in northwestern Montana. M.S. Thesis, Univ. MT, Missoula. 134 pp.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Mono. No. 4. 174 pp.

Capp, J. C. 1967. Competition among bighorn sheep, elk, and deer in Rocky Mountain National Park, Colorado. M.S. Thesis, CO State Univ., Ft. Collins. 133 pp.

Conrad, C. E., and C. E. Poulton. 1966. Effect of a wildfire on Idaho fescue and bluebunch wheatgrass. J. Range Manage. 19(3): 138-141.

Constan, K. J. 1972. Winter foods and range use of three species of ungulates. J. Wildl. Manage. 36(4):1068-1076.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37(3):451-460.

Couey, F. M. 1950. Rocky Mountain bighorn sheep in Montana. MT Fish Game Comm., Helena. Bull. 2. 90 pp.

________, and A. Schallenberger. 1971. Bighorn sheep. Game Management in Montana. MT Fish Game Dept., Helena. Fed. Aid Proj. W-3-C:97-105.

Cowan, I. McT. 1950. Some vital statistics of big game on over-stocked mountain range. Trans. N. Amer. Wildl. Conf. 15:581-588.

________. 1974. Management inplications of behavior in the large herbivorous mammals. Pages 921-934 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN Morges, Switzerland.

Cox, Ross. 1831. Adventures on the Columbia River. Henry Colburn and Richard Bently, London. Vol. I, p. 231.

Craighead, J. J., M. G. Hornocker, M. W. Shoesmith, and R. I. Ellis. 1969. A marking technique for elk. J. Wildl. Manage. 33(4): 906-909.

________, F. C. Craighead, Jr., R. L. Ruff, and B. W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison drainage as determined by biotelemetry. Wildl. Mono. No. 33. 50 pp.

Daubenmire, R., and J. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. WA Agri. Exp. Sta., Pullman. Tech. Bull. 60. 104 pp.

Dearden, B. L., R. E. Pegau, and R. M. Hansen. 1975. Precision of microhistological estimates of ruminant food habits. J. Wildl. Manage. 39(2):402-407.

Demarchi, R. A. 1968. Chemical composition of bighorn winter forages. J. Range Manage. 21(6):385-388.

Erickson, G. L. 1972. The ecology of Rocky Mountain bighorn sheep in the Sun River area of Montana, with special reference to summer food habits and range movements. M.S. Thesis, MT State Univ., Bozeman. 50 pp.

Erickson, J. A. 1970. Use of drop net and collars in study of Dall sheep. Trans. Northern Wild Sheep Council, pp. 20-21.

Ferris, W. A. 1873. Life in the Rocky Mountains. A dairy. Special collection, Univ. MT Library, Missoula.

Flook, D. R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128 in D. J. Crisp, ed. Grazing in terrestial and marine environments. Brit. Ecol. Soc. Symp. No. 4 - Blackwell Scientific Publ., Oxford.

Geist, V. 1971. Mountain sheep; a study in behavior and evolution. Univ. Chicago Press, Chicago and London. 383 pp.

________. 1975. On the management of mountain sheep: theoretical considerations. Pages 77-98 in J. B. Trefethen, ed. The wild sheep in modern North America. The Boone and Crockett Club and Winchester Press, New York.

Gilbert, P. F., O. C. Wallmo, and R. B. Gill. 1970. Effect of snow depth on mule deer in Middle Park, Colorado. J. Wildl. Manage. 34(1):15-23.

Grubb, P., and P. A. Jewell. 1966. Social grouping and home range in feral Soay sheep. Symp. Zool. Soc. London 18:179-210.

Harrison, J. L. 1958. Range of movement of some Malayan rats. J. Mammal. 39(2):180-206.

Hayne, D. W. 1949. Calculation of size of home range. J. Mammal. 30(1):1-18.

Hirst, S. M. 1975. Ungulate-habitat relationships in a south African woodland/savanna ecosystem. Wildl. Mono. No. 44. 60 pp.

Honess, R. F., and N. M. Frost. 1942. A Wyoming bighorn sheep study. WY Game Fish Dept., Cheyenne. Bull. 1. 127 pp.

Howard, V. W., Jr. 1967. Identifying fecal groups by pH analysis. J. Wildl. Manage. 31(1):190-191.

________, and D. G. DeLorenzo. 1974. Specific differentiation of herbivore pellet groups by pH. J. Wildl. Manage. 38(4):948-949.

Hunter, G. N., T. R. Swen, and G. W. Jones. 1946. The trapping and transplanting of Rocky Mountain bighorn sheep in Colorado. Trans. North Amer. Wildl. Conf. 11:364-371.

Kelsall, J. P., and W. Prescott. 1971. Moose and deer behavior in snow. Can. Wildl. Serv. Report Series No. 15. 27 pp.

Krausman, P. R., E. D. Ables, and C. M. McGinnis. 1974. Deer identification through pellet pH. J. Wildl. Manage. 38(3):572-573.

Loveless, C. M. 1967. Ecological characteristics of a mule deer range. CO Game Parks Dept., Denver. Tech. Pub. No. 20. 124 pp.

Lemmon, P. E. 1957. A new instrument for measuring forest overstory density. J. For. 55(9):667-668.

Marcum, C. L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Ph.D. Thesis, Univ. MT, Missoula. 188 pages.

Matthews, J. W. 1973. Ecology of bighorn sheep on Wildhorse Island, Flathead Lake, Montana. M.S. Thesis, Univ. MT, Missoula. 88 pp.

McCann, L. J. 1956. Ecology of the mountain sheep. Amer. Midl. Nat. 56(2):297-324.

McCullough, D. R., and E. R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. CA Fish Game, Sacremento. 52(2):68-84.

Mendenhall, W. 1971. Introduction to probability and statistics. 3rd ed. Wadsworth Publishing Co., Belmont, CA. 499 pp.

Moen, A. N. 1968. Energy balance of white-tailed deer in the winter. Trans. North Amer. Wildl. Nat. Resources Conf. 33:224-236.

________. 1973. Wildlife Ecology. W. H. Freeman and Co., San Francisco. 458 pp.

Moser, C. A. 1962. The bighorn sheep of Colorado. CO Game, Fish Parks Dept., Denver. Tech. Pub. No. 10. 49 pp.

Nagy, J. G., and J. G. Gilbert. 1968. Fecal pH values of mule deer and grazing domestic sheep. J. Wildl. Manage. 32(4):961-962.

Neff, D. J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32(3): 597-614.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38(3):541-545.

Nicholls, T. H., and D. W. Warner. 1972. Barred owl habitat use as determined by radiotelemetry. J. Wildl. Manage. 36(2):213-224.

Nie, N. H., C. H. Hall, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. SPSS: Statistical package for the social sciences. McGraw-Hill,

Oldemeyer, J. C. 1966. Winter ecology of bighorn sheep in Yellowstone National Park. M.S. Thesis, CO State Univ., Ft. Collins. 107 pp.

_________, W. J. Barmore, and D. L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. J. Wildl. Manage. 35(2):257-269.

Peek, J. M., D. L. Urich, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildl. Mono. No. 48. 65 pp.

Penfound, W. T. 1967. A physiognomic classification of vegetation in conterminous United States. Bot. Rev. 33:289-326.

Peterson, R. O., and D. L. Allen. 1974. Snow conditions as a parameter in moose-wolf relationships. Le Naturaliste can. 101:481-492.

Pfister, R. D., S. F. Arno, R. C. Presby, and B. L. Kovalchik. 1972. Preliminary forest habitat types of western Montana. USDA For. Serv., Intermountain For. and Range Exp. Sta. 75 pp.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1974. Forest habitat types of Montana. Intermountain For. and Range Exp. Sta. and Northern Region, USFS, Missoula, MT. 213 pp.

Putnam, E. F. 1950. Trapping bighorn sheep in Wyoming. WY Wildl. 14(8):12-15, 33-36.

Rutherford, W. H. 1972a. Guidelines for evaluating bighorn sheep transplanting sites in Colorado. CO Game, Fish Parks, Denver. Game Inform. Leafl. No. 93. 3 pp.

________. 1972b. Status of transplanted bighorn sheep in Colorado. CO Game, Fish Parks, Denver. Game Inform. Leafl. No. 92. 3 pp.

Schallenberger, A. D. 1965. Food habits, range use and inter-specific relationships of bighorn sheep in the Sun River area, west central Montana. M.S. Thesis, MT State Univ., Bozeman. 44 pp.

Shafer, E. L., Jr. 1963. The twig-count method for measuring hardwood deer browse. J. Wildl. Manage. 27(3):428-437.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. J. Wildl. Manage. 39(2):387-401.

Simmons, N. M. 1961. Daily and seasonal movements of Poudre River bighorn sheep. M.S. Thesis, CO State Univ., Ft. Collins. 182 pp.

Smith, D. R. 1954. The bighorn in Idaho, its status, life history and management. ID Fish Game, Boise. Wildl. Bull. 1. 154 pp.

Sparks, D. R., and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscope technique. J. Range Manage. 21(4):264-265.

Spencer, C. C. 1943. Notes on the life history of Rocky Mountain bighorn sheep in the Tarryall Mountains of Colorado. J. Mammal. 24(1):1-11.

Stelfox, J. G. 1971. Bighorn sheep in the Canadian Rockies: a history 1800-1970. Canad. Field Nat. 85(2):101-122.

________. 1975. Range ecology of Rocky Mountain bighorn sheep in Canadian national parks. Ph.D. Thesis, Univ. MT, Missoula. 234 pp.

Stickney, P. F. 1966. Browse utilization based on percentage of twig numbers browsed. J. Wildl. Manage. 30(1):204-206.

Sugden, L. G. 1961. The California bighorn in British Columbia. B.C. Dept. Rec. and Cons., Victoria. 58 pp.

Telfer, E. S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Manage. 34(3):553-559.

Todd, J. W., and R. M. Hansen. 1973. Plant fragments in the feces of bighorns as indicators of food habits. J. Wildl. Manage. 37(3):363-366.

Vallentine, J. F. 1971. Range development and improvements. Brigham Young Univ. Press, Provo. 516 pp.

Woodgerd, W. 1964. Population dynamics of bighorn sheep on Wildhorse Island. J. Wildl. Manage. 28(2):381-391.

Yoakum, J. 1963. Reestablishing native bighorn ranges. Trans. Desert Bighorn Council 7:122-125.